ACIDIC PRECIPITATION IN ONTARIO STUDY:

TERRESTRIAL EFFECTS PROGRAMME NORTHWESTERN REGION

BEDROCK, SOIL AND VEGETATION STUDIES AROUND ACID SENSITIVE LAKES IN PUKASKWA NATIONAL PARK, ONTARIO

Prepared for

The Acidic Precipitation in Ontario Study

The Ontario Ministry of the Environment

By

SENES Consultants Limited

In Association With

Lakehead University

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1.0 INTRODUCTION

Chemical and biological effects of acidic deposition on North American lakes have been observed in sensitive areas where atmospheric wet sulphate (SO_4^{-2}) deposition exceeded 20 kg/ha/y (Bangay and Riordan, 1983). In Pukaskwa National Park, Ontario, Canada, Chan (1985) and Bangay and Riordan (1983) estimated wet SO_4^{-2} deposition at 15.6 and 15-20 kg/ha/y, respectively. In the park, however, many extremely sensitive lakes (bicarbonate $\leq$ 40 ueq/L) and three acidic lakes (pH $\leq$5.0) were observed (Sutton et al., 1983). Previous soil surveys in the park by Duff et al., (1983) indicate that these soils may be sensitive to acidification.

In 1983, Lakehead University under contract to the Ministry of the Environment (MOE) as part of the Acidic Precipitation in Ontario Study (APIOS) initiated detailed pedological and geological investigations around eight low pH lakes (5.0-6.5). The objectives of these surveys were: 1) to describe and classify the physical and chemical characteristics of soils and bedrock in an area receiving relatively low acid inputs but where acidification effects apparently occur, 2) to establish a database against which future surveys could be compared; 3) to evaluate any terrestrial parameters which may indicate detrimental atmospheric deposition. To assist in the evaluation of the soil study sites, the vegetation at the soil study sites was also described in studies during 1984 and 1985.

Preliminary results of the soil and rock studies have been reported in Viitala and Barclay (1985). An abbreviated description of these studies was also presented at the Muskoka '85 International Symposium on Acidic Precipitation, as a poster; and a manuscript has been submitted for publication (Viitala et al., 1985). The purpose of this report is to describe in detail the studies carried out at the Pukaskwa soil study sites.

2.0 DESCRIPTION OF STUDY AREA

Pukaskwa National Park is located on the northeastern shore of Lake Superior

(Figure 1), where a cool, moist climate with mild summers (July x 16°C) and cold winters (January x -13°C), prevails. July mean daily maximum temperatures reach 21°C. Mean annual precipitation and snowfall are 85 and 285 cm, respectively (Chapman and Thomas, 1968). Fog and cloud are relatively common. Precipitation pH (1980, volume weighted mean) is approximately 4.5 (Bangay and Riordan, 1982). Results from seven months of precipitation monitoring in 1984 in Pukaskwa Park indicate that most rainfall events with pH < 4.2 had air parcel trajectories originating in the west and southwest sectors (Chan, 1985).

Most of the park is rockland, with many areas of shallow soil and exposed bedrock. The bedrock is mostly low nutrient granites but there are also areas of metamorphic rocks with higher cation amounts (Duff et al., 1983). The topography of these rockland areas is fractured and very uneven. From Lake Superior to the highest point in the park there is an elevation change of 450 metres.

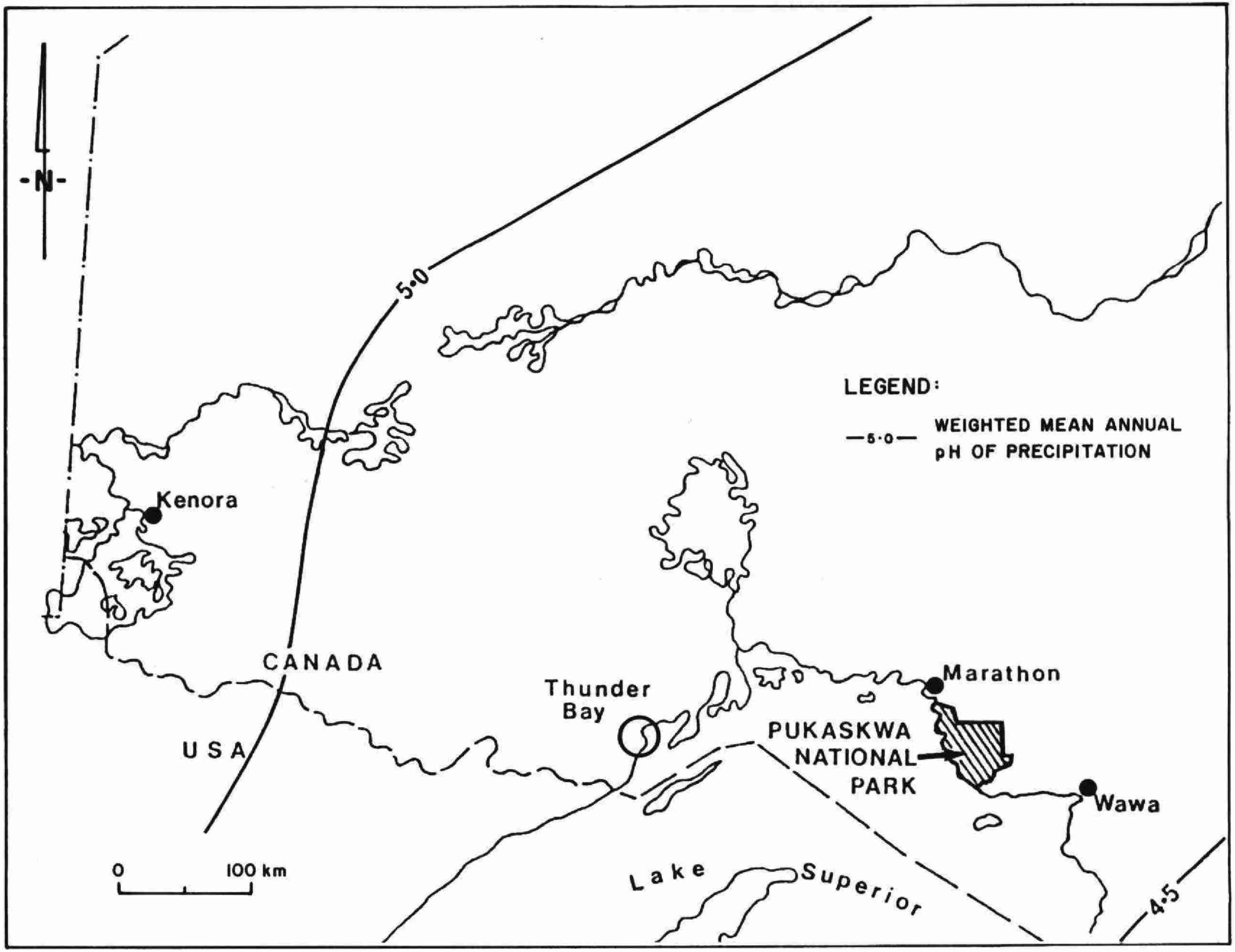
The mostly shallow soils are acidic and made up of soils that are podzolic, brunisolic, gleysolic and organic. The soils of Pukaskwa have been described in Duff et al. (1983).

The vegetation of Pukaskwa is variously classified as strongly humid southern boreal, by Ahti (1964); as low boreal, by Zoltai (1983); and as Boreal Forest, Superior Section, by Rowe (1972). There have been some vegetation-related studies in the park. Garton (1976), produced a checklist that consists primarily of vegetation accessible from the Lake Superior coast. A more detailed study has been done by Gimbarzevsky et al. (1978); this study includes descriptions of a number of forest types in the park as well as a checklist.

Because the interior of Pukaskwa Park is remote from roads and lake access, and because of very difficult terrain, the Park has large unlogged areas. As is common in the boreal forest, fires have been frequent. However, many of the forest areas are rather fire-resistant, owing to dissected topography and

FIGURE 1

PUKASKWA NATIONAL PARK



large areas of open rock between forest areas. The fire history of Pukaskwa Park is currently under study; some aspects of the study have been described by Alexander (1978, and 1980).

In addition to fire, there has been another important biological factor in most of the study area. From 1975 to 1985 there was a moderate to severe spruce budworm (Choristoneura fumiferana) outbreak, described in detail by Weir et al. (1984) and Howse and Applejohn (1985). The outbreak resulted in considerable modification of the balsam fir and white spruce component in the Pukaskwa forest.

Watersheds of the eight most sensitive lakes in the park were selected for study. Seven lakes exhibited dystrophic but not "bog" characteristics, whereas the unnamed lake MOE 9 was clearly oligotrophic (Table 1). The bicarbonate concentration (HCO_3^-) of all lakes was less than 80 ueq/L. Three lakes were acidic (pH 5.0, $HCO_3^- \leq 0$ ueq/L) and had elevated inorganic monomeric aluminum levels (98-124 ug/L). Sulphate was the main anion. Acid tolerant plankton species were also evident in low pH lakes (MOE, 1985).

On all tables and figures the lakes are listed in order of most acidic to least acidic. When on some figures lines connect values observed at the different lakes this is done solely to help the reader interpret the figure and does not represent any other relationship.

The area of the eight acidic lakes is inland, away from the major effects of Lake Superior (Figure 2). It is also at rather high elevations: 310 metres to 435 metres (Lake Superior is 183 metres). There is no evidence of logging at any of the lakes and only MOE-9 is a relatively young fire forest; the other seven sites are mature forests with uneven age class distributions.

The bedrock associated with the eight study lakes is primarily granitic with intrusions of pegmatite, porphyry, and diabase. This granitic bedrock has, at all eight lakes, a thin overlay (<100 cm) of soil that is classified, using the Canadian System of Soil Classification, as acid Humo-Ferric Podzols

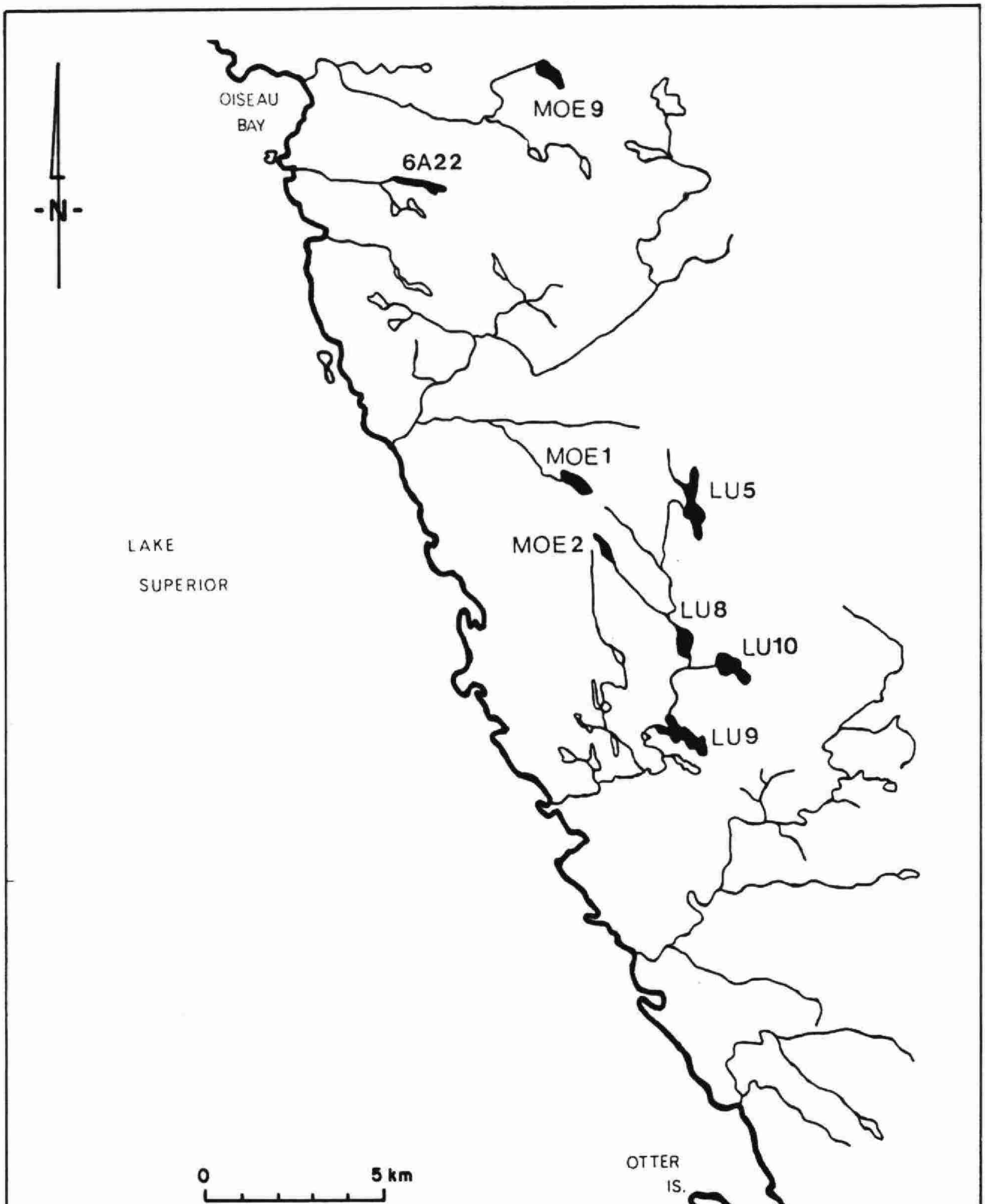
TABLE 1 CHEMICAL AND PHYSICAL CHARACTERISTICS OF STUDY LAKES

LAKE	pH[1]	HCO_3^-	$SO_4^=$	$A^=$[2]	Ca^{++}	Mg^{++}	Fe	Al	Alim[3]	Pb	TOTAL P	COND[4]	COLOUR[5]	DOC	ELEVATION	MEAN DEPTH	SURFACE AREA	WATERSHED AREA
	µeq/l						µg/l					µS/cm	H U	mg/l	m		ha	
LU 8	4.99	-7.2	92.8	67.4	69.9	24.7	201	493	124	<3	9	22	75	8.8	370	3.9	17	2320
LU 5	4.98	-6.8	93.2	68.2	64.9	24.7	210	430	98	<3	8	21	77	8.6	435	6.2	21	1000
MOE 1	5.05	-7.0	107.2	48.0	69.9	24.7	181	388	115	<3	7	21	42	6.5	435	5.3	13	100
MOE 2	5.65	16.0	113.8	45.5	94.8	32.9	125	279	55	<3	6	23	29	5.8	420	8.4	9	105
LU 9	5.94	31.2	105.5	61.8	114.8	41.2	117	297	24	<3	9	23	49	7.1	335	3.6	36	3630
LU 10	6.13	35.8	98.8	62.2	99.8	32.9	105	280	24	<3	11	22	48	6.5	380	3.3	22	800
MOE 9	6.47	56.2	89.4	36.3	109.8	32.9	48	48	2	<3	6	21	14	3.1	385	7.4	31	144
6A22	6.35	78.4	113.6	46.4	154.7	41.2	83	84	5	<3	7	28	25	4.8	310	5.1	11	180
$\overline{X}$	5.70	27.2	101.8	54.5	97.3	31.9	134	287	56	3	8	23	45	6.4	384	5.4	20	1035
RANGE R MIN / MAX	4.98 / 6.47	0 / 78.4	89.4 / 113.8	36.3 / 68.2	64.9 / 154.7	24.7 / 41.2	48 / 210	48 / 493	2 / 124	-	6 / 11	21 / 28	14 / 77	3.1 / 8.8	310 / 435	3.3 / 8.4	9 / 36	100 / 3630
STD DEV s	0.57	29.0	9.6	11.9	30	6.8	58	157	49.9	-	1.7	2.3	22.6	1.9	45.6	1.8	9.6	1293
COEFF VAR C.V.(%)	10	107	9	22	46	28	43	55	89	-	21	10	50	30	12	33	48	125

1 - 5 GLOSSARY OF TEST PARAMETERS TABLE 5.

FIGURE 2

LOCATION OF STUDY LAKES IN PUKASKWA NATIONAL PARK



(Viitala et al., 1985).

3.0 MATERIALS AND METHODS

3.1 Bedrock and Soil Study

Field

In July, 1983, representative soil sample sites around the eight Pukaskwa study lakes were selected by air photo interpretation and field checked on the basis of soil depth and development. Because of the difficult terrain, transportation to all of the lakes was by a float-equipped helicopter. Soil pit sites were located part way up shoreline slopes and dug to the parent material. The exposed profiles were describe in detail using the methods outlined by Bates et al., (1982) and subsequently classified according to McKeague (1978a). At several locations between sample pit sites, general soil characteristics were determined for samples obtained with a Dutch auger. Rock chip samples were collected from bedrock outcrops along the shoreline.

Laboratory

Soil samples were air dried at room temperature on plastic trays. Part of the soil organic horizon (LFH, FH) was separated and saved for rubbed-fibre content determination. The balance of the samples were sieved into two parts: less than 2 mm (fine earth) and greater than 2 mm (gravel). The percent gravel in the soil was calculated.

The degree of particle roundness and identity of minerals in the gravel fraction were determined. The fine earth fraction was analyzed for the following chemical and physical properties according to McKeague (1978b): pH (in water and in 0.01 M $CaCl_2$) exchangeable Ca, Mg, K and Al, cation exchange capacity (CEC), organically bound Fe, Al, and Mn, organic C, total carbonate, total N, available P, soluble SO_4, available Al, trace metals Cu, Zn, Ni, and Pb, total percent sand, silt and clay, Munsell soil colour and sand size

classification. Petrographic thin section of the rock samples were examined microscopically to determine rock type, degree of weathering, mica alteration, and metallic content.

3.2 Vegetation Study

Field studies in Pukaskwa were carried out on 12 September 1984 (Lakes LU-8, MOE-1, and MOE-9), 21 May 1985 (Lakes LU-5, LU-9, LU-10, and 6A-22), and 18 June 1985 (LU-8, and MOE-2). A general description of the forest was made at each study site. This description includes observations relating to the different vegetation strata in the study area; also, when time permitted, notes were made of any other vegetation types observed and of the forest area around the whole lake.

The vegetation studies relate particularly to the soil studies done in 1983. Therefore, these soil pit areas had to be found. To reduce impact on the park environment, these pits were unmarked in 1983, and therefore some of the exact pit locations were difficult to find in 1984-85. Pits were not found at LU-8-S1, LU-9-S1, and LU-10-S1. At these sites, descriptions of the general soil pit areas were made.

Once the study area was located, a 10 x 10 metre quadrat was marked, with the soil pit in the centre. Lists were prepared for all species of trees (woody and > 2 metres tall), shrubs, dwarf shrubs (woody but trailing on the ground), herbs, bryophytes, and lichens. A Braun-Blanquet cover scale estimate was made for all species in the quadrats. Also, the dbh was measured for the four largest individuals of up to four dominant tree species. Any unknown vascular plants, bryophytes or lichens were collected.

In the time available after the quadrat was completed, the general area around the quadrat was observed and species not found inside the plot were listed. Some collections were also made in these areas. Any plant collections that were made were pressed. Duplicate sets were made, for Pukaskwa National Park and for the National Museum.

Once species lists had been completed, single axis polar ordinations (Bray and Curtis, 1957) were calculated to determine study area relationships. All species were used for these ordinations.

Nomenclature of the vascular plants is according to Scoggan (1978-79); mosses are according to Ireland (1980); liverworts are according to Stotler and Crandell-Stotler (1977); and lichens are according to Hale (1979).

4.0 RESULTS

4.1 Bedrock and Soil Study

Geology

The batholithic granitic rocks that dominate the study area are of early Precambrian ($\geq$60 M.y) lithological age (Table 2) (Bennett and Thurston, 1977). Rock types include: biotite quartz monzonite, trondhjemite, quartz monzonite, porphyritic granite, granite, pegmatite, and biotite-granite gneiss. The average mineral composition of these granitic rocks is 60 percent quartz, 30 percent feldspar and 10 or less percent mica with traces of various other minerals. The dominant feldspar is the potassium-rich microcline feldspar. Granites are medium to coarse grained with local foliations and porphyritic textures. The trondhjemite rocks consist of mainly (40-70%) feldspar with interstitial quartz. Microcline feldspar shows perthitic growth patterns. Trace minerals are in the form of biotite, chlorite, epidote and hornblende. Quartz monzonite rocks differ slightly from the trondhjemites in that microcline feldspar forms 20-40% of the rock. Showings of trondhjemite, quartz monzonite, granite, pegmatite, and granite gneiss with amphibolite are found at LU-5, 6A22, MOE-1, MOE-9, and LU-8 respectively (Table 3 and Figures 3 to 10). (The abbreviations used on the tables and figures are explained on Table 9 which follows Page 25.)

Confirmation of a pegmatitic phase to the granitic batholith is shown by the

TABLE 2 . TABLE OF LITHOLOGIC UNITS FOR THE PUKASKWA RIVER AND UNIVERSITY RIVER AREA.

PHANEROZOIC	
CENOZOIC	
QUATERNARY	
RECENT	1 million years ago
Swamp and stream deposits	
PLEISTOCENE	1 - 4 m.y.
Till, sand and gravel (moraines, eskers)	
UNCONFORMITY	
PRECAMBRIAN	550 m.y.
LATE PRECAMBRIAN	
KEWEENAWAN	
Dacite	
UNCONFORMITY	
EARLY TO LATE PRECAMBRIAN	550 m.y.
LATE MAFIC INTRUSIVE ROCKS	
Diabase, olivine diabase, quartz diabase, gabbro	
INTRUSIVE CONTACT	
EARLY PRECAMBRIAN (ARCHEAN)	
INTERMEDIATE TO FELSIC INTRUSIVE ROCKS	
KABENUNG LAKE STOCK AND MISHIBISHU LAKE STOCK	
Porphyritic monzonite, porphyritic quartz monzonite, porphyritic quartz-bearing monzonite	
BATHOLITHIC GRANITIC ROCKS	
Biotite quartz monzonite, biotite trondhjemite, quartz monzonite, hornblende trondhjemite, hornblende-quartz monzonite, porphyritic granite, hybrid granite, migmatite, pegmatitic muscovite granite, pegmatite, aplite, hornblende diorite-gneiss, biotite granite-gneiss	
INTRUSIVE CONTACT	
WILDER LAKE COMPLEX	
Hornblende diorite, quartz diorite, hornblende porphyry (diorite), gneissic granite, hybrid granite, gneissic diorite, gneissic granite-diorite, minor gabbro	
INTRUSIVE CONTACT	
METASEDIMENTS	
Conglomerate, polymictic conglomerate, greywacke, arkose, sandstone arkose, argillite, slate, iron formation and ferruginous sandstone	
METAVOLCANICS	
FELSIC TO INTERMEDIATE METAVOLCANICS	
Dacite to rhyolite flows, felsic to intermediate tuff and volcanic breccia, felsic to intermediate agglomerate, porphyritic dacite (intrusive), quartz-feldspar porphyry (flows and sills)	
MAFIC TO INTERMEDIATE METAVOLCANICS AND RELATED INTRUSIVE ROCKS	
Basalt, andesite, amygdaloidal basalts, pillow basalt to andesite, porphyritic basalt, gneissic amphibolite, amphibolite, chlorite schist, chlorite-biotite schist, gabbro, porphyritic gabbro	
IRON FORMATION	

SOURCE: BENNETT AND THURSTON, 1977

TABLE 3. Summary of outcrop geology around each study lake.

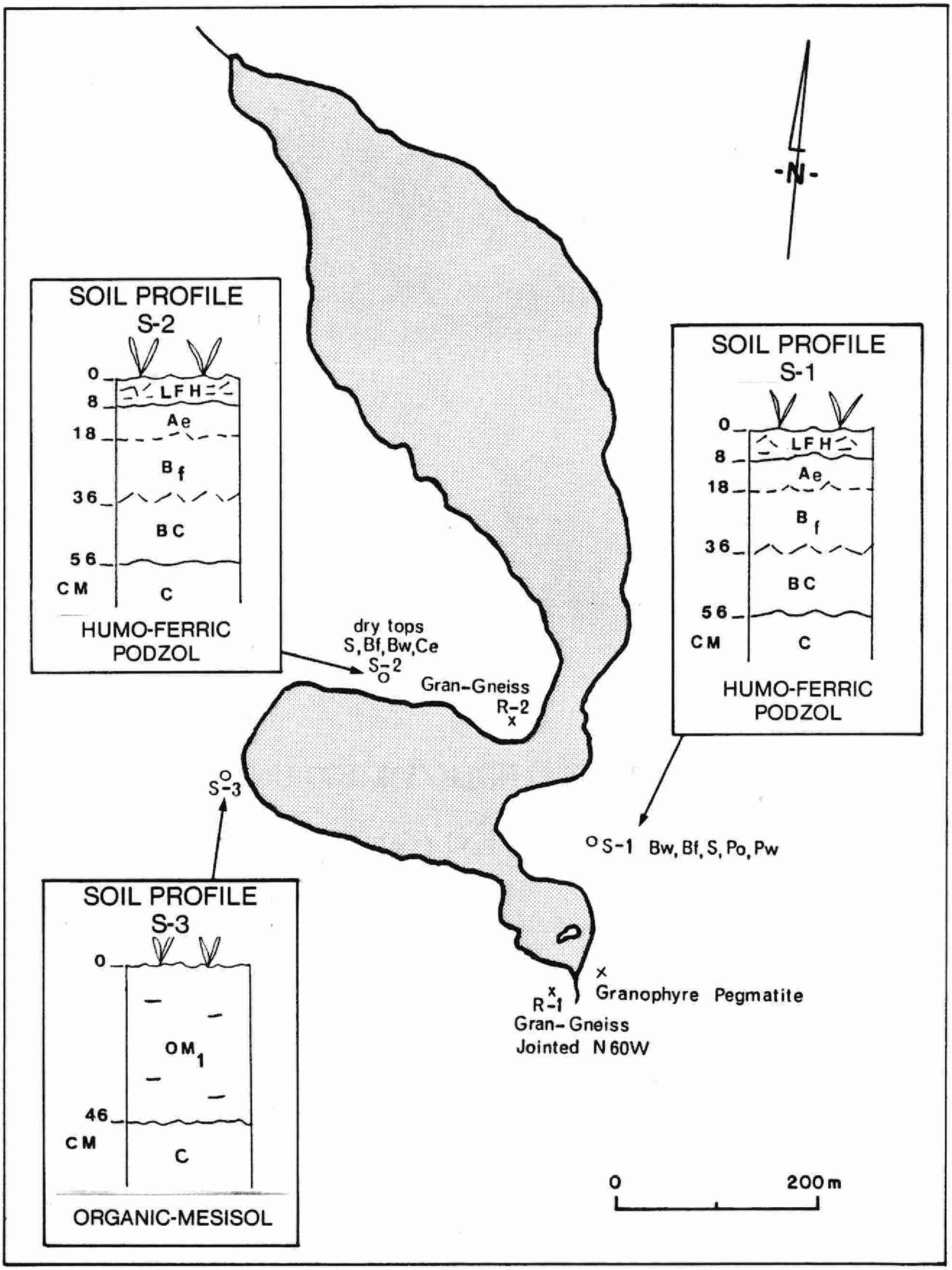
SAMPLE LOCATION	ROCK TYPE	DOMINANT MINERALS % QRT	FELD	MICA	TRACE MINERALS	DEPTH OF SURFACE WEATHERING (cm)	REMARKS
LU-8 South-east	Amphibolite Granite Gneiss	60	30	10	Chlorite, Mica Amphibolite Qrt, Feld Horneblende	1.0	-oxidized along fractures and gneissosity -pegmatite veins
LU-8 West side	Granite	60	30	10	Pyrite, Hematite, Magnetite	0.5	-highly fractured -in contact with felsic porphyry -medium grained
LU-5 East side	Alkaline Feldspar Granite and Felsic Porphyry Trondhjemite	35	50	15	Pyrite, Garnet Arsenopyrite Fe-oxide	0.5	-5mm thick books or mica along grain boundaries -Perthitic feldspar crystal growth -Fe-oxide along grain boundaries -some pegmatite veins -coarse grained
MOE-1 East & West	Granite Quartz-Monzonite	50	35	15	Chlorite, Apatite, Nepheline, Sodalite, Fe-oxides, Hematite-stains	1.0	-slightly altered -mica along grain boundaries -Qrt inclusions in feldspar -medium grained
MOE-1 North	Felsic Porphyry and Pegmatite	35	60	5	Pyrite, Garnet, Magnetite Hematite and Uranium stains Scheelite	0.5	-oxidized along joints -perthitic feldspar growth patterns
MOE-2 West	Granite Granite-Biotite Gneiss Pegmatite	60	30	10	Magnetite Pyrite Chlorite	0.5	-slightly altered -fine mica as in-clusions -larger mica as grain boundaries -K-rich feldspar

TABLE 3. Continued.

SAMPLE LOCATION	ROCK TYPE	DOMINANT MINERALS % QRT	FELD	MICA	TRACE MINERALS	DEPTH OF SURFACE WEATHERING (cm)	REMARKS
LU-9 East & West	Granite	60	30	10	Chlorite, Magnetite, Fe-oxides Muscovite-Mica	1.0	-slightly altered -some weathering along fractures and joints -coarse grained
LU-10 East & West	Granite	55	35	10	Epidote Garnet, Magnetite, Muscovite-Mica Chlorite, Pyrite	0.5	-slightly altered -medium grained
MOE-9 West	Syanite and Granophyre	25	65	10	Magnetite Pyrite Fe-oxides Sulph-stains	0.5	-Felsic K/Na intergrowth
West	Amphibolite Gran-Gneiss	-	-	-	Cu, Ni, Fe-Sulphide stains -chlorite -epidote -amphibole	1.0	-slightly altered -Qrt as inclusions -Oxidized along gneissosity
MOE 6A22 East & West	Granite	60	30	10	Chlorite Pyrite Magnetite	0.5	-slightly altered -fine mica inclusions -K-feldspars show perthitic growth patterns -Medium grained

FIGURE 3

STUDY LAKE LU-8



STUDY LAKE LU-5

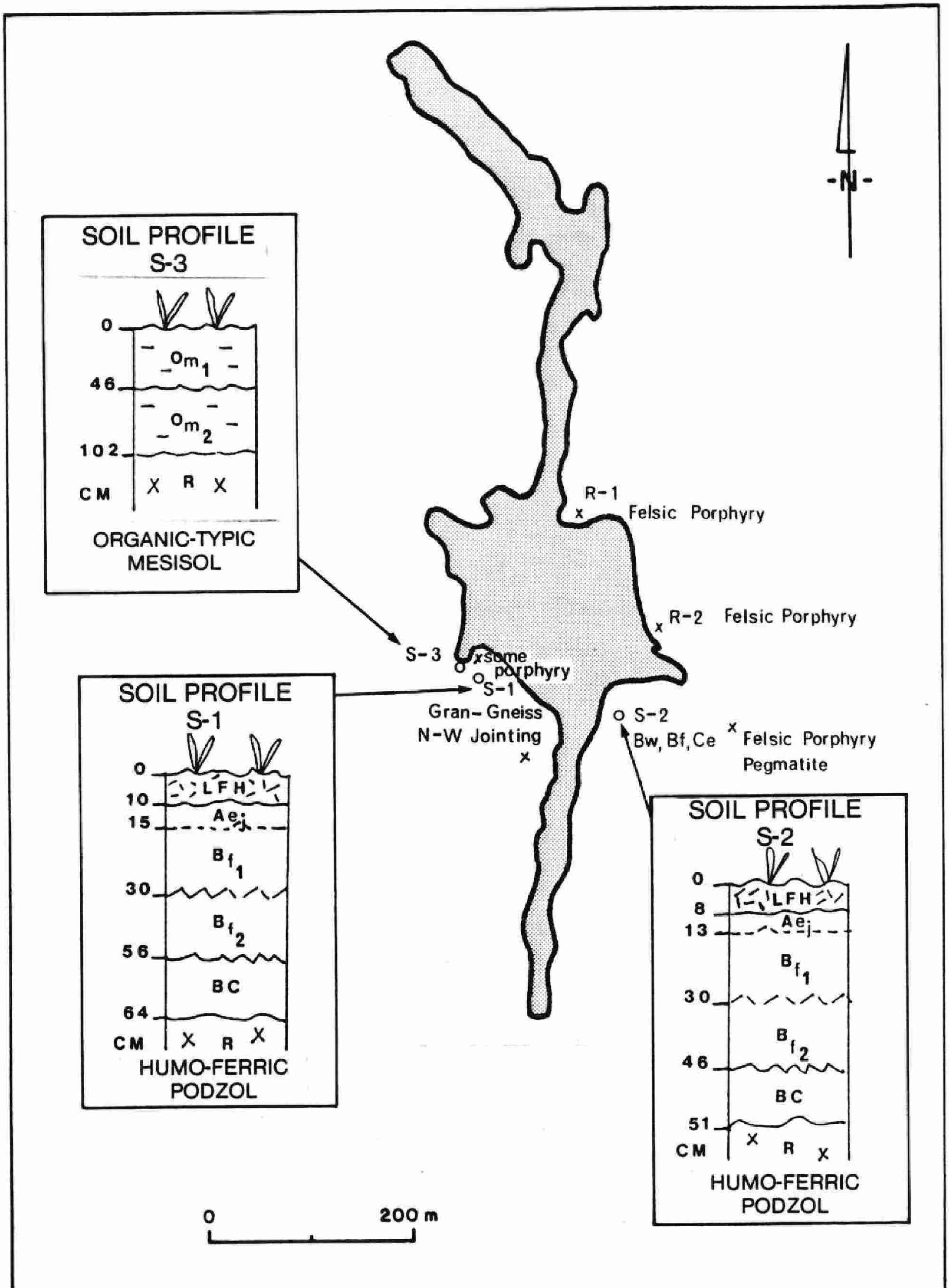


FIGURE 5

STUDY LAKE MOE-1

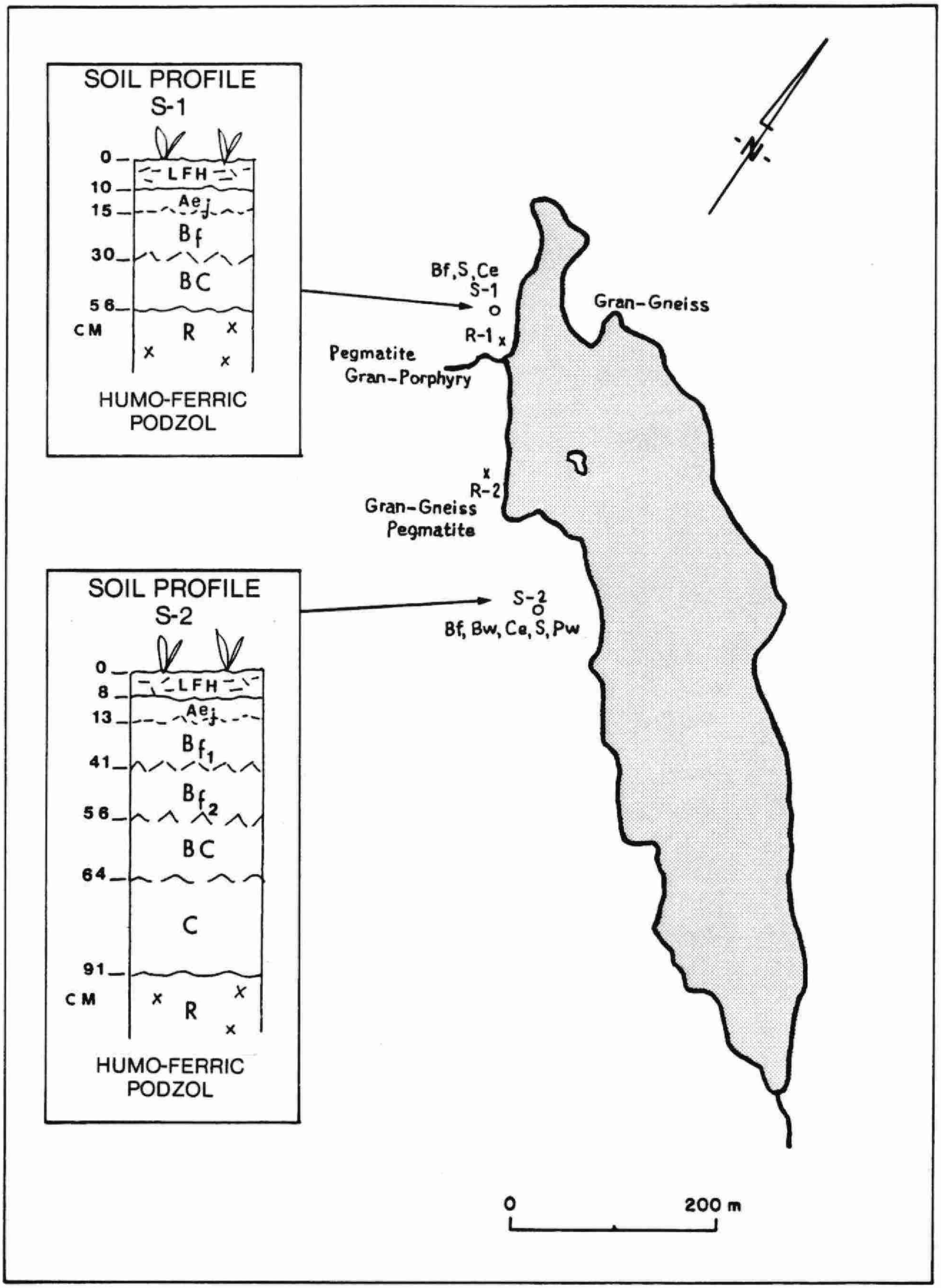
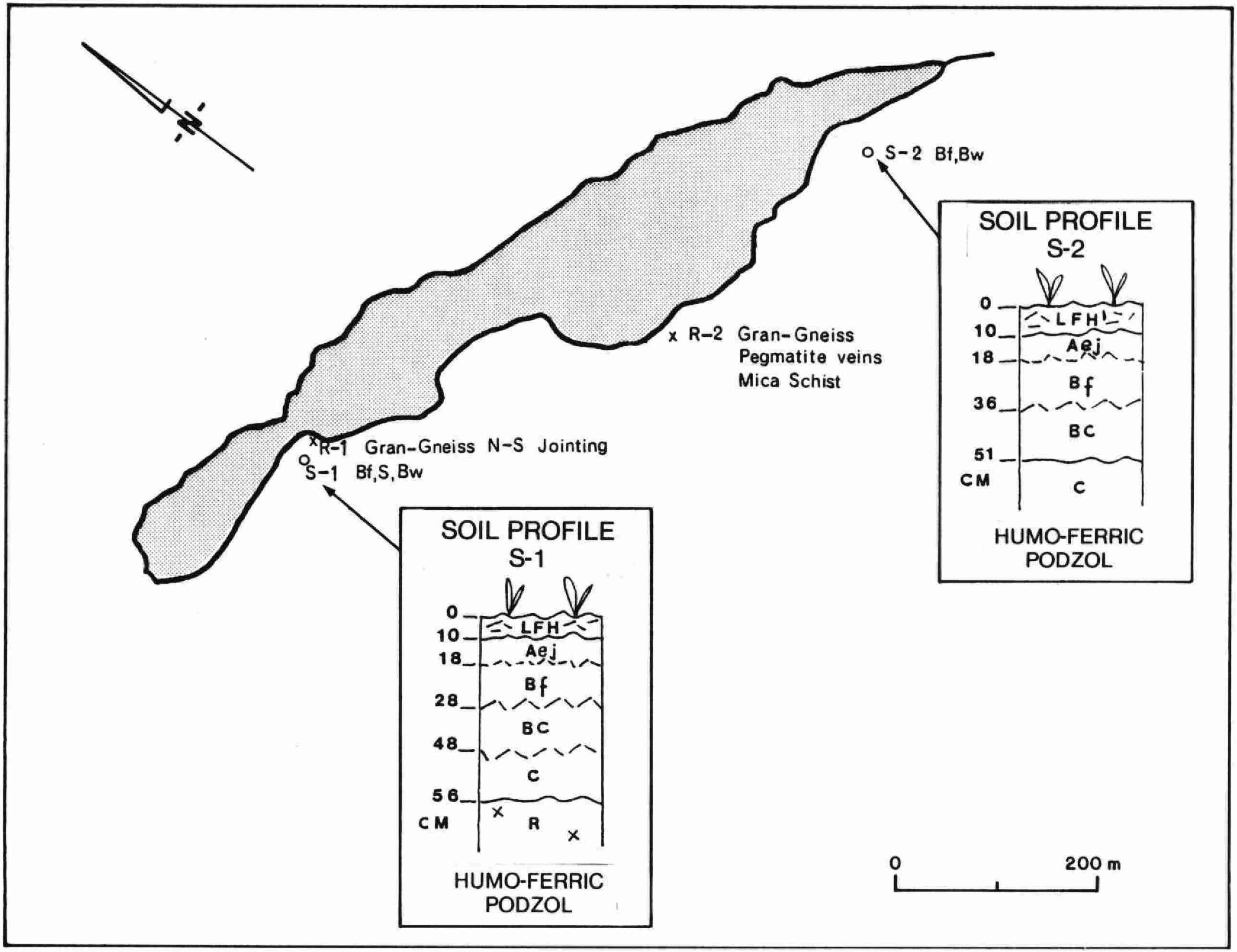


FIGURE 6

STUDY LAKE MOE-2



STUDY LAKE LU-9

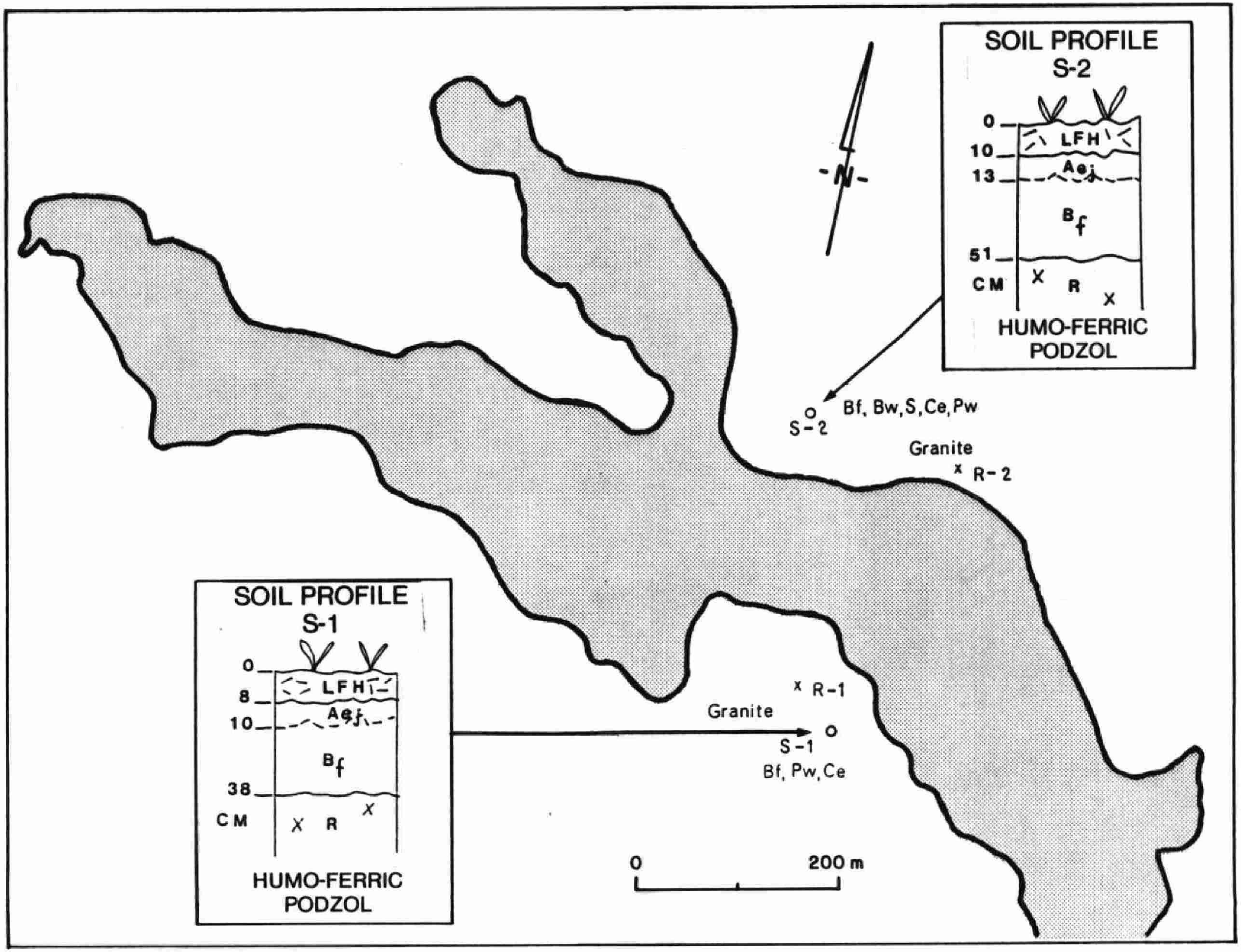


FIGURE 8

STUDY LAKE LU-10

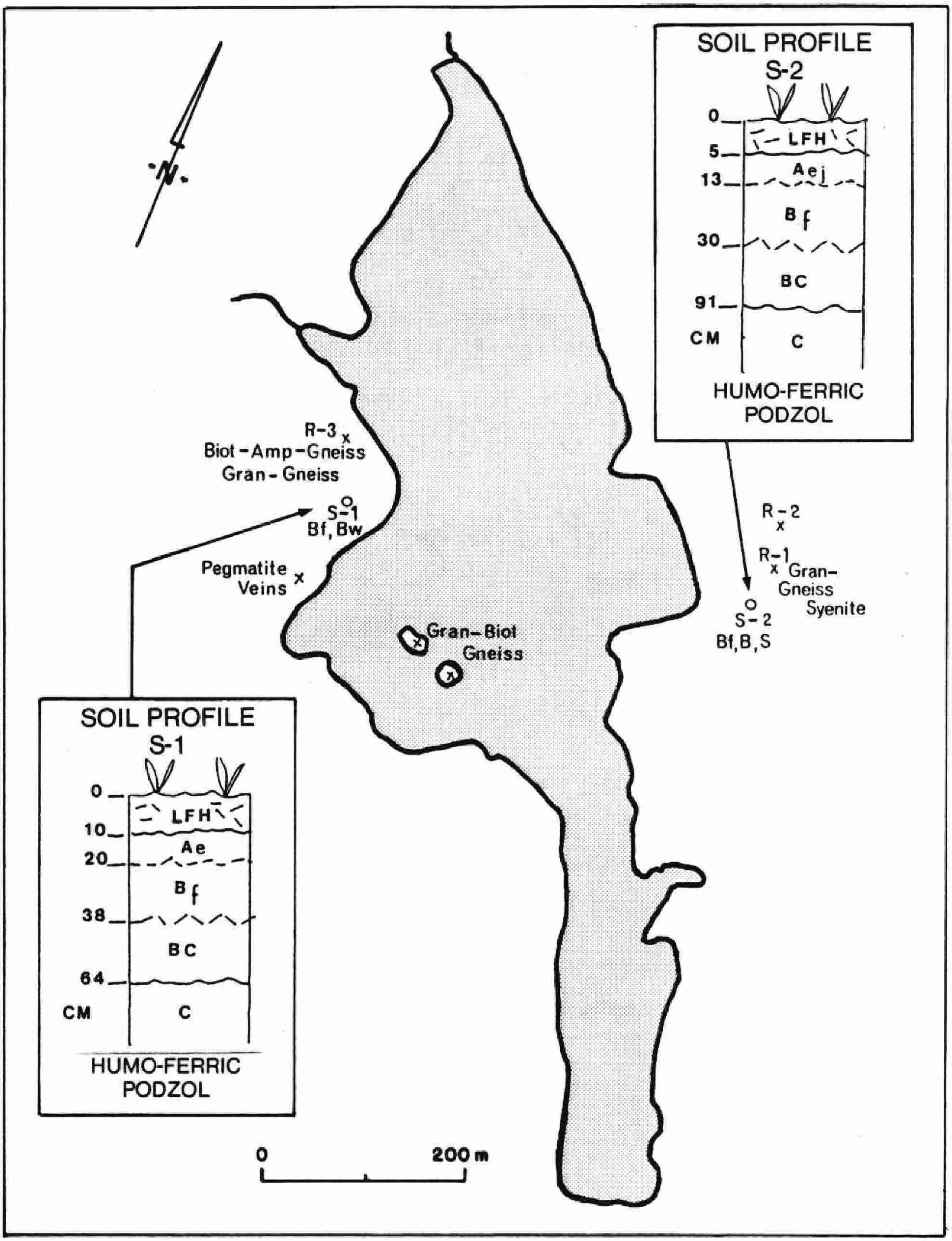
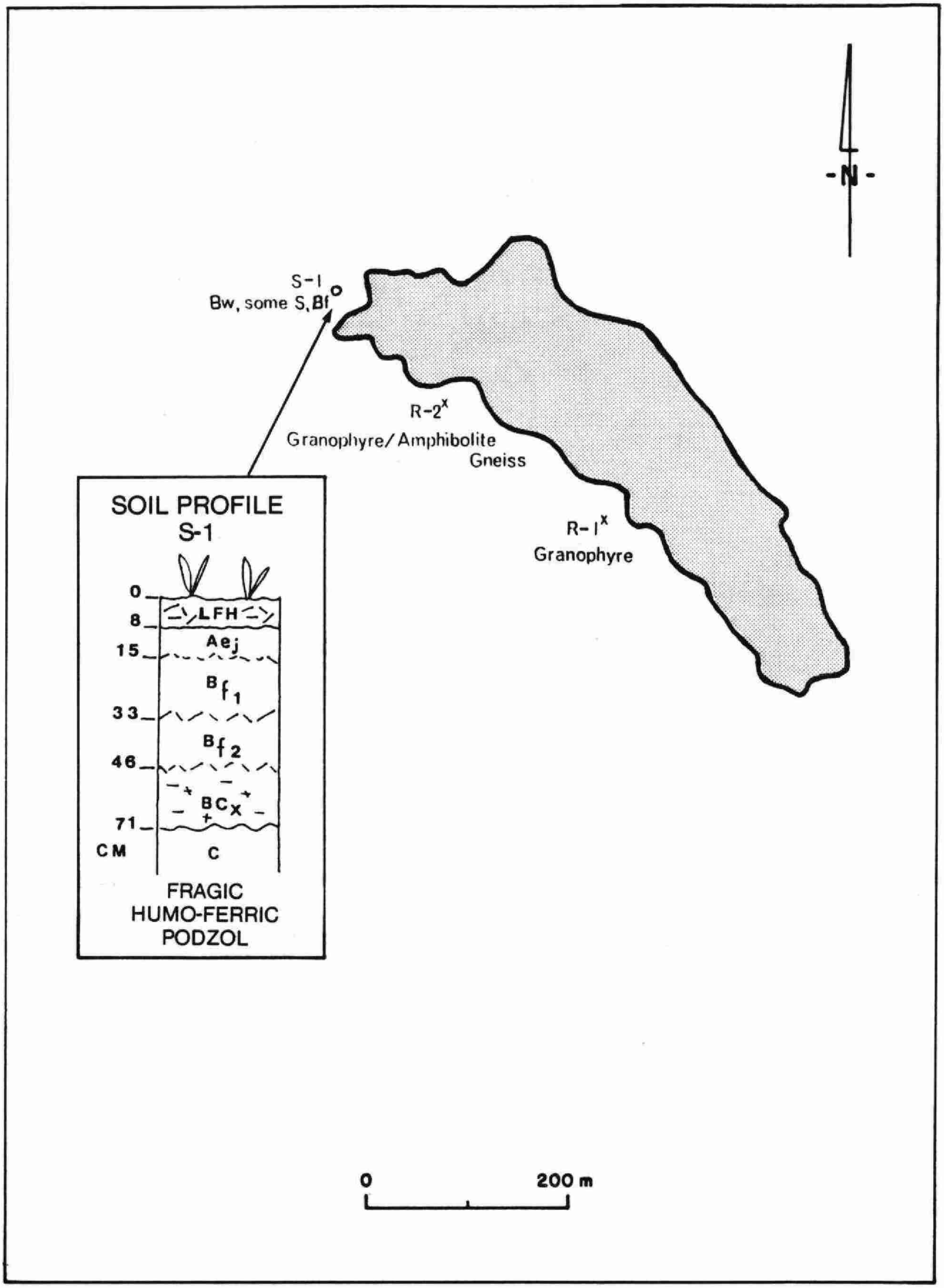
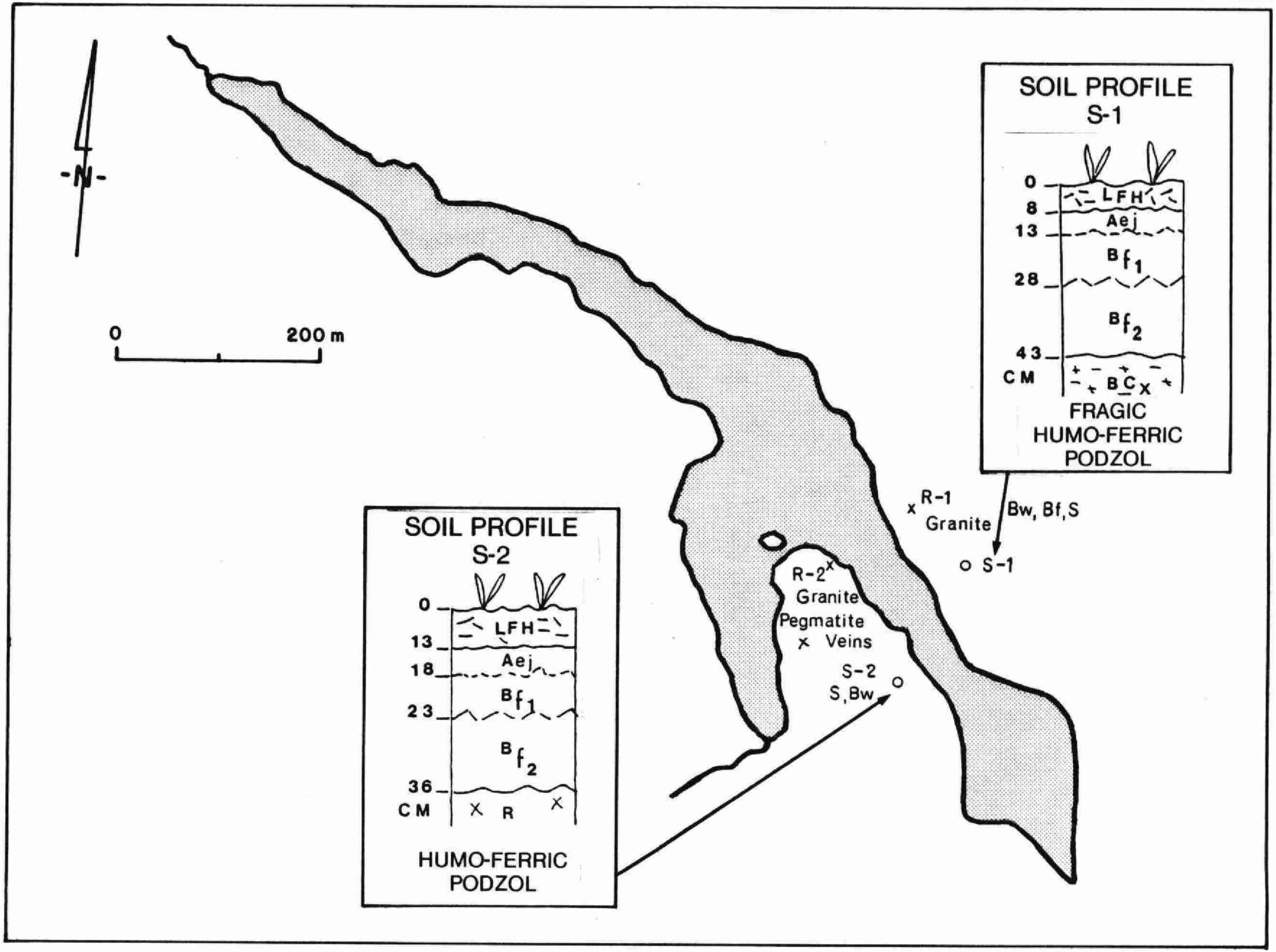


FIGURE 9

STUDY LAKE MOE-9



STUDY LAKE 6A-22



presence of chlorite, epidote, garnet and muscovite mica minerals in the bedrock at LU-5, LU-10 and MOE-9. These same alteration product minerals of chlorite, epidote and garnet indicate that the granitic rocks were metamorphosed under regional greenshist facies conditions. More intense metamorphism of gneissic-amphibolite and hornefels facies show a response to the intrusion of granitics at localized contact area, such as found at LU-8.

Regionally characteristic olivine diabase dykes were not found at the eight study lakes area. These dykes within the Pukaskwa Park area generally strike northwest with a 50 degree dip to the northeast. One of these dykes at the Pukaskwa Depot has been potassium-argon dated to 1030 M.y ago (Wanless, 1970).

Glaciation

The average direction of ice movement over this area was about S20W during the Wisconsin ice sheet advance period of about 9,000 years ago. The most common surficial deposit is a thin ($\leq$ 100 cm) blanket of glacial till with some thicker deposition on south slopes of hills.

Valley and lowland areas consist of silt, sand and gravel deposited by meltwater as the ice-sheet withdrew to the north, northeast. There were distinct phases to the post-glacial period in the Pukaskwa area (Bennett and Thurston, 1977). During the Wisconsin ice-sheet, the entire Lake Superior basin was occupied by a single continuous glacial lake known as Lake Minong, which had an elevation of about 110 metres above the present level of Lake Superior (Farrand, 1960). Subsequently, the lake level fell by gradual and discontinuous stages to a low of 75 metres below the present lake level. The new lake was known as Lake Houghton.

As the ice front retreated northward, glacial unloading and resulting rebound raised the outlet of the Great Lakes Basin resulting in a continuous rise in the level of the Great Lakes to form a single lake called Lake Nipissing. Near the mouth of the Pukaskwa River, the Nipissing Great Lakes reached their maximum elevation of about 30 metres above the present lake level

approximately 4,400 years ago (Farrand, 1960). Since then, it has subsided to its present level of 183 metres above sea level.

Pedology

Soils of Podzolic order are dominant on the Canadian Shield region, as in the study area in Pukaskwa Park, and in total make up about 25 percent of Canada's land area. Podzolic soils occur under forest or heath vegetation in boreal or cryoboreal, humid soil climates. They usually have organic surface horizons composed of forest litter, that are underlain by light-coloured eluvial horizons, followed by brownish-red B-horizons, enriched with amorphous materials composed mainly of organic matter combined with aluminum and iron. Parent material is mostly coarse textured and acidic. Three great groups, Humo-Ferric, Ferro-Humic and Humic Podzol, recognize increasing degrees of accumulation of carbon, aluminum and iron and broadly reflect increased humidity of the soil environment.

Classification criteria for a Podzol soil are determined by the characteristics of the B-horizon and the typical horizon sequence of the profile. A typical podzolic B-horizon is $\geq$10 cm thick, contains $\geq$0.5 percent organic carbon and sodium phyrophosphate extractable aluminum plus iron total $\geq$0.6 percent in textures finer than sand and $\geq$ 0.4 percent in sands. This B-horizon varies in colour from black to red with yellowing at depth.

The B-horizon can be further subdivided into a Bf (0.5-5.0% organic carbon) or a Bhf ($\geq$5.0% organic carbon) horizon. Typical horizonation is LFH, Ah, Ae, Bf or Bhf, BC and C within the one-metre control section of the profile.

Results of the soil study are summarized on Table 4 and Figures 3 to 10. The complete laboratory results are contained in Appendix C. Soil profiles taken around the eight lakes were found to be predominantly Humo-Ferric Podzols and were developed on similar parent material of glacial origin. Parent material is generally less than 100 cm deep over granitic bedrock. Degree of roundness (subangular) of the gravel fraction particles and their mineralogy show that

TABLE 4 ROCK AND SOIL CHARACTERISTICS NEAR STUDY LAKES.

STUDY SITE	— BEDROCK — TYPE	TRACE MINERALS	— SOIL — DEPTH TO BEDROCK cm	GRAVEL[1] CONTENT %	GRAVEL ROUNDNESS AND MINERALOGY	PARENT MATERIAL	TEXTURE % TOTAL S	TEXTURE % TOTAL Si	TEXTURE % TOTAL CL[2]	ORGANIC HORIZON (LFH. FH) [3] RUBBED FIBRE %	[4] H_2O PH	[5] TOTAL N mg/g	[6] $SO_4^=$ µg/g	Ca µg/g	Mg µg/g	[7] K µg/g	[8] Pb µg/g	[9] Mn %	[10] CEC meq/100 g	Bf[1] HORIZON[11] Fe %	Bf[1] HORIZON[11] Al %
LU 8	GRANITE-GNEISS PEGMATITE	CHLORITE MICA MAGNETITE PYRITE HEMATITE	> 100	42	SUBANGULAR GRANITICS TRACE SHALE	GLACIO FLUVIAL TILL	77 / 90	20 / 10	3 / 0	55	4.3	16.8	280	2600	390	1300	69	.072	4.8	1.00	0.79
LU 5	GRANITE-GNEISS FELSIC	PYRITE GARNET ARSENO PYRITE Fe OXIDES	58	24	SUBROUNDED GRANTICS TRACE IGNEOUS	GLACIAL TILL	63 / 64	32 / 33	5 / 3	70	3.5	10.8	95	2400	290	580	61	.007	4.5	0.70	1.10
MOE 1	GRANITE-GNEISS PEGMATITE	CHLORITE PYRITE APATITE HEMATITE	74	33	SUBANGULAR GRANITICS	GLACIAL TILL	63 / 84	30 / 15	7 / 1	53	3.6	12.7	115	2950	350	675	76	.014	6.8	1.70	1.35
MOE 2	GRANITE-GNEISS MICA SCHIST	CHLORITE PYRITE MAGNETITE	56	26	SUBANGULAR GRANITICS	GLACIAL TILL	56 / 55	33 / 43	11 / 2	61	3.7	11.3	175	2450	340	560	69	.008	5.2	1.20	1.60
LU 9	GRANITE	CHLORITE MICA MAGNETITE PYRITE Fe OXIDES	45	20	SUBROUNDED FELSIC PORHYRY GRANITE GNEISS	GLACIAL TILL	44 / 63	50 / 34	6 / 3	45	4.1	10.7	165	3200	310	675	80	.021	5.1	1.20	1.03
LU 10	BIOTITE GRA GNEISS SYENITE	CHLORITE MICA EPIDOTE PYRITE MAGNETITE	> 100	15	SUBANGULAR GRANITICS TRACE SHALE	GLACIO FLUVIAL TILL	72 / 82	24 / 15	4 / 3	65	3.7	11.6	120	2550	380	635	73	.017	4.7	1.20	0.90
MOE 9	AMPHIBOLITE BIOTITE-GNEISS GRANOPHYRE	CHLORITE PYRITE MAGNETITE Fe OXIDES	> 100	3	SUBANGULAR FELSIC PORHYRY TRACE IGNEOUS	GLACIO FLUVIAL SAND	85 / 94	14 / 5	1 / 1	70	3.9	6.5	170	2600	73	710	68	.011	3.2	0.60	0.76
6A22	GRANITE PEGMATITE	CHLORITE PYRITE MAGNETITE	40	22	SUBANGULAR GRANITICS TRACE SHALE	GLACIO FLUVIAL TILL	40 / 87	58 / 12	2 / 1	65	3.4	10.0	94	2350	390	495	47	.005	4.8	1.30	0.98
$\bar{X}$				23			63 / 77	33 / 21	5 / 2	61	3.8	11.3	152	2638	315	704	68	.019	4.6	1.11	1.06
RANGE R $\frac{MIN}{MAX}$				$\frac{3}{42}$			$\frac{40}{85}$ $\frac{63}{94}$	$\frac{14}{58}$ $\frac{5}{43}$	$\frac{1}{11}$ $\frac{0}{3}$	$\frac{45}{70}$	$\frac{3.4}{4.3}$	$\frac{6.5}{16.8}$	$\frac{94}{280}$	$\frac{2350}{3200}$	$\frac{73}{390}$	$\frac{495}{1300}$	$\frac{47}{80}$	$\frac{.005}{.072}$	$\frac{3.2}{6.8}$	$\frac{0.60}{1.70}$	$\frac{0.76}{1.60}$
Std DEV s				11.6			16 / 15	15 / 14	3 / 1	8.8	0.3	2.9	41.4	280	105	251	10	0.03	1.0	0.35	0.28
COEFF VAR C.V. (%)				50			25 / 19	45 / 67	60 / 50	14	8	26	27	11	33	36	15	158	22	32	26

1 - 11 GLOSSARY OF TEST PARAMETERS TABLE 5.

TABLE 5. Glossary of Test Parameters

CHEMICAL AND PHYSICAL CHARACTERISTICS OF STUDY LAKES (Table 1).

1. Mean H+ concentration expressed as pH
2. Organic acid anion estimated from pH and DOC (after Oliver, 1983).
3. Inorganic monomeric aluminum
4. Specific conductance.
5. Hazen units.

ROCK AND SOIL CHARACTERISTICS NEAR STUDY LAKES (Table 4).

All Soil Profiles are of Humo-Ferric Podzol Order, Methods and Classifications Based on Canadian System of Soil Classification, 1978.

1. Soil percent gravel: (≥ 2mm) by weight of total sample. Mean of total profile.
2. Soil texture - total: (sand) 2mm-53μm (silt) 53-2μ (clay)≤ 2μm. B and C horizon recorded respectively.
3. Percent rubbed - fibre content: (Humisol) ≤ 15. (Mesisol) 15-45. (Fibrisol) ≥ 45.
4. pH in water at 1:1 : Weight of soil to volume of water.
5. Total nitrogen. Kjeldahl: 78% of N total in profile occurs in organic soil horizon.
6. SO_4 water extractable: 77% of SO_4 total in profile occurs in organic soil horizon.
7. Ca,Mg,K - sodium chloride extractable: 93%, 93% and 90% respectively of Ca, Mg and K total in profile occurs in organic soil horizon.
8. Pb - total: 81% of Pb total in profile occurs in organic soil horizon.
9. Mn - Dithionite extractable: 64% of Mn total in profile occurs in organic soil horizon.
10. CEC - (Cation Exchange Capacity) expressed at pH of 4.5 (20% base saturation): 75% of CEC total in profile occurs in organic soil horizon.
11. Fe Al - Dithionite Extractable: 50% of Fe and Al total in profile occurs in Bf soil horizon.

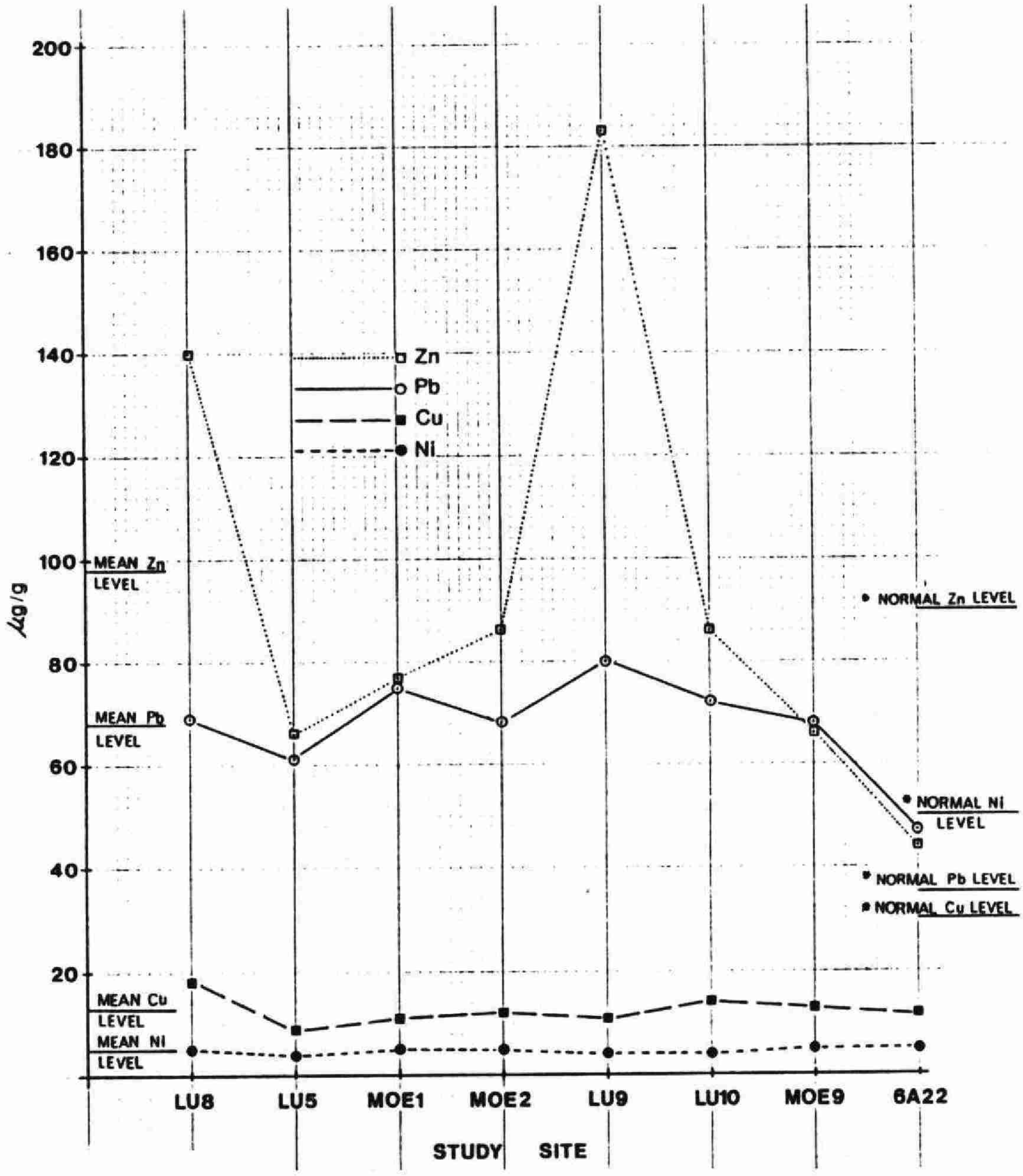
these thin, coarse textured soils were derived from the local granitic bedrock. Traces of subrounded shale and diabase were found in the gravels of reworked till materials at LU-8, LU-5, LU-10, MOE-9 and 6A22. Textures are coarse sands with a mean gravel content of 23 percent by weight. Soil clay content did not exceed 11 percent. Texture of the solum (B-horizon) is sandy loam containing about 63 sand, 33 silt and 4 percent clay. The parent material (C-horizon) is slightly coarser loamy sand with about 77 percent sand, 21 percent silt and 2 percent clay. No carbonates were detected when tested with 6 normal HCl.

Rubbed-fibre content of the soil surface organic horizons was $\geq$45 percent, thereby classifying them as fibric. The organic matter is only slightly decomposed and consists mainly of woody materials. Water pH reaction in the soil profile ranges from 3.4 (extremely acidic) in the surface organic horizon (LFH) to 5.2 (strongly acidic) in the parent material (C) horizon. The low pH of the profile indicates that only about 20 percent of the cation exchange capacity is available for plant-root nutrient uptake. At these low base saturation levels, the soil cation exchange capacity decreases below 6.8 meq/100 g, which classifies the area as "sensitive" to acidic deposition according to McFee (1980) sensitivity classes (Sensitive $\leq$6, Moderately Sensitive 6-15, or Non-Sensitive $\geq$15 meq/100g).

Trace metal analyses of the soil surface horizons (LFH) (Figure 11) show that copper and nickel levels are lower that those considered normal according to general guidelines established by Brown (1970) and Vinogradov (1958). Zinc content in these horizons is higher than normal at two (LU-8 and LU-9) of the eight lakes. Lead levels however, are above normal, according to these general guidelines, at seven of the eight lake areas with only one, 6A22 being near normal. Mean lead level within the soil surface horizon was 68 ug/g dry weight, and below 5 ug/g in the soil parent material. Microscopic examination of petrographic thin-sections of bedrock showed no evidence of lead-containing minerals. This suggests an accumulation of lead in the soil surface horizons.

FIGURE 11

METAL CONCENTRATIONS OF LFH HORIZONS



* (Ref: BROWN, H.J. 1979. "ENVIRONMENTAL CHEMISTRY OF THE ELEMENTS", ACADEMIC PRESS, LONDON)

Iron, aluminum and manganese are naturally abundant in podzolic soil. Leaching of these substances at above normal rates can occur when precipitate pH levels fall below 4.5. Soil leaching experiments as part of the APIOS programme with acidic solutions of simulated rainfall support this view. Surrounding bedrock geology and soil gravel mineralogy also show potassium-rich minerals which seem to account for the somewhat higher potassium level ($\bar{x}$ 704 ug/g) found in the soil.

Evidence of soil mineral sulphide, oxide and trace metal leachate stains exists on the interface contact of shallow acidic soil with acidic granitic bedrock.

4.2 Vegetation Study

General Vegetation Descriptions of the Study Site Areas

Primarily, the following are descriptions of the soil pit study areas. They are also general descriptions of the forest areas around the eight lakes visited. These are necessarily generalizations, as only part of each area could be observed directly. They include some notes on small vegetation areas that are not necessarily relevant to the soil pit study areas, but which are included because so few vegetation studies have been done in this part of Pukaskwa Park. Soil characteristics for the soil pits at the centre of the vegetation quadrats are shown on Table 6.

Lake LU-8, Soil Pits S_1 and S_2

Two soil pit areas were studied at this lake. The pit at S_1 could not be located but the S_2 pit was found. There is a mixed mature forest at this lake. Over-mature white birch (*Betula papyrifera*) is the major dominant. There is also a large component of balsam fir (*Abies balsamea*), though most of the fir are dead as a result of budworm defoliation. White cedar (*Thuja occidentalis*) and black and white spruce (*Picea mariana* and *P. glauca*) are

Table 6

CHARACTERISTICS OF THE SOIL PITS AT THE VEGETATION PLOTS

	LU-8	LU-5	MOE-1	MOE-2	LU-9	LU-10	MOE-9	6A22	$\bar{X}$
	S_1	S_1	S_2	S_2	S_1	S_1	S_1	S_2	
Depth to Bedrock (cm)	56	64	91	51	38	64	71	36	59
pH (water) LFH or FH	4.3	3.5	3.9	3.7	4.1	3.7	3.9	3.4	3.7
pH (water) BC horizon	5.3	5.0	5.7	4.4	4.6	4.8	5.0	5.3	4.8

also present. Large white pines (Pinus strobus) are evident on the higher ridges around the lake. Partly owing to the balsam fir mortality, this is a rather open forest. There is a moderate to sparse shrub layer, dominated by balsam fir regeneration. Other shrub species are mountain ash (Sorbus decora), mountain maple (Acer spicatum), and Vaccinium spp. including mountain bilberry (V. membranaceum). Because this is a rather open forest there is a well-developed herb and dwarf shrub layer. Bracken fern (Pteridium aquilinum) and Canada bunchberry (Cornus candensis) are important herbs. Also present in quantity are blue-bead lily (Clintonia borealis), shining club moss (Lycopodium annotinum), and wild lily-of-the-valley (Mianthemum canadense). There is a poorly developed bryophyte and lichen layer that is mostly confined to fallen logs, dead stumps, hummocks in the soil, and boulders.

There is a soil pit at S_3 in an organic soil. This is a poor fen dominated by Carex spp. and Sphagnum magellanicum. There are scattered small trees of white cedar and black spruce. Shrub species present include sweet gale (Myrica gale), meadow sweet (Spirea alba), leatherleaf (Chamaedaphne calyculata), bog laurel (Kalmia polifolia), and bog rosemary (Andromeda glaucophylla).

At the south end of the lake near the outflow creek a small wet area contains sweet gale, royal fern (Osmunda regalis), bog clubmoss (Lycopodium inundatum) and closed gentian (Gentiana linearis).

Lake LU-5, S_1

The forest around this lake is dominated by white birch but there is also a great deal of white cedar, especially in areas near the lake. Black and white spruce are important. Balsam fir is also present and previous to the spruce budworm infestation must have been at least equal to the white cedar. There is a sparse to dense shrub layer with some areas of thick balsam fir and white cedar regeneration. Mountain ash and mountain bilberry are also important in the shrub layer. There is a sparse to moderate herb layer, dominated by bracken fern but also containing substantial amounts of Lycopodium ssp., wild

lily-of-the-valley, gold thread (Coptis groenlandica) and Canada bunchberry. The bryophyte layer is sparse and there are only small amounts of ground lichens present.

MOE-1,S_2

This is a high lake in a rugged area. This is mostly an old conifer forest with substantial blow-down. White cedar is the dominant tree species. Balsam fir has been an important component but there are now many dead trees, owing to budworm attack. Other important tree species are black spruce and white birch. There are large white pines on the ridges. The shrub layer is sparse with some white cedar and balsam fir regeneration. Also, mountain ash and mountain bilberry are present. There is a sparse to moderate herb layer dominated by blue-bead lily, Canada bunchberry, and wild lily-of-the-valley. The bryophyte and lichen layer is sparse and mostly limited to the old wood of stumps and logs, and to boulders.

MOE-2,S_2

This is a long, steep-sided lake that runs east and west. The soil pit S_2 is on the south side. This is a mixed, rather open forest, dominated by mature and over-mature white birch. There is a good population of black spruce as well, including many mature trees. Balsam fir is also present but many are dead from defoliation by spruce budworm. White cedar is found along the lake shore and occasionally in the forest. Some large white pines are present on the ridges. The shrub layer is generally sparse but with areas of dense balsam fir regeneration. The dominant shrub is mountain bilberry, but mountain ash and mountain juneberry (Amelanchier bartramiana) also are commmon. There is a well-developed, often dense, herb layer. Canada bunchberry is the dominant herb species. Other common herbs are wild lily-of-the-valley, bluebead lily, bracken fern, wild sarsaparilla (Aralia nudicaulis) and shining club moss. The bryophyte and lichen layer is sparse and mostly confined to the old wood of stumps and logs.

A wet area near the study area contains white cedar, Sphagnum sp., beech fern (Dryopteris phegopteris), and oak fern (Gymnocarpium dryopteris).

LU-9,S_1

This lake has a mostly overmature mixed forest dominated by white birch and white cedar. There is also balsam fir but this species is much reduced owing to spruce budworm-caused mortality. Black and white spruce are also present with white pine mostly confined to ridge aeas. There is a sparse to moderate shrub layer made up primarily of white cedar and balsam fir regeneration, but it also contains quantities of mountain ash, mountain bilberry, and mountain juneberry. There is a moderate to good herb layer with wild lily-of-the-valley and bracken fern as dominants. The bryophyte and lichen layer is sparse and mostly confined to stumps, logs and soil hummocks.

LU-10,S_1

This study area is a quite open mixed forest, dominated by rather large mature white birch. This forest appears to be younger than the forest at most of the other sites. Balsam fir is also common and in this stand there is some budworm-caused mortality but most of the fir is alive. White spruce is well represented but black spruce is rare. White cedar is also rare except along the lake shore. The shrub layer is generally sparse; however, it is made up of several species. Mountain ash, mountain bilberry, sweet-top blueberry, mountain juneberry, and balsam fir regeneration are all present. There is a good herb layer at this site. Bracken fern, Canada bunchberry, and wild lily-of-the-valley are common. Several other herbs are also well represented. The bryophyte and lichen layer is mosty sparse and restricted to stumps, logs, and boulders.

6A22,S_2

This is an old, semi-open mixed forest dominated by black spruce, with white birch as a secondary species. There is white cedar near the lake. Patches of

trembling aspen can be seen, as well as white pine on the exposed ridges. The shrub layer is sparse to moderate and most of the shrubs are under one metre in height. Labrador tea is the dominant shrub, but mountain juneberry, red maple, and sweet-top blueberry are also common. There is a good herb and dwarf shrub layer. Bracken fern is very common. Also common are trailing arbutus (Epigaea repens), wild lily-of-the-valley, northern star flower (Trientalis borealis), and teaberry (Gaultheria procumbens). There are few ground lichens, but there is a good soil bryophyte layer dominated by Pleurozium schreberi and Dicranum polysetum.

Dominant Trees of the Study Area

The dominant tree species of the study sites and their mean diameters are given in Table 7. In five of the sites, there are four dominants, two sites have three dominants, and site 6A22 has only two dominants. In all but site 6A22, white birches are the largest trees. In most cases, each mean figure is the mean of four trees. However, occasionally, there were not four individuals of a species suitable for measurement in the 10 x 10 metre soil pit quadrats. The details of the number of individuals measured and the diameters of each tree measured are given in Appendix A.

Dominant Plant Species

All vascular plants that were recorded in the 10 x 10 metre quadrats and that have at least six percent cover (2 on the Braun-Blanquet Scale) are listed in Table 8. This list includes 6 trees, 15 shrubs, 11 herbs, 3 sub-shrubs, 9 bryophytes (8 mosses and 1 liverwort) and 3 lichens. In the case of the bryophytes and lichens, if the species has one percent cover or more, it is included in the list.

There are a number of species present in the study areas that are not dominants. These species are either too low in cover to be categorized as dominants or are listed only as present in the general study area. A complete list of all recorded species is given in Appendix B. This list includes 10

TABLE 7. Mean d.b.h. of the dominant trees in the 10 x 10 metre quadrats. Units are centimetres.

	LU-8 S_2	LU-5 S_1	MOE 1 S_2	MOE 2 S_2	LU-9 S_1	LU-10 S_1	MOE 9 S_1	6A22 S_2
Betula papyrifera	25.2	27.6	28.0	21.9	29.3	28.3	13.7	12.3
Abies balsamea	11.0	2.5	13.8	10.3	12.4	13.6	4.9	-
Picea mariana	7.6	-	41.8	14.1	11.7	-	6.3	13.1
Picea glauca	11.2	2.5	-	-	-	13.5	8.9	-
Thuja occidentalis	-	3.4	20.5	-	19.7	-	-	-

TABLE 8. Cover of Dominant Species. Vascular species with at least 6% cover. Bryophytes and lichens with at least 1% cover. Braun-Blanquet Scale: + = rare, 1 = 1 - 5%, 2 = 6 - 25%, 3 = 26 - 50%, 4 = 51 - 75%, 5 = 76 - 100%. S = soil pit 10 x 10 metre quadrat. G = general area around the quadrat. P = present and dominant. * = most trees dead due to spruce budworm. All species are listed most common to least common order.

	LU-8 S_1		LU-8 S_2		LU-5 S_1		MOE-1 S_2		MOE-2 S_2		LU-9 S_1		LU-10 S_1		MOE-9 S_1		6A22 S_2		Presence
	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	
Trees:																			
Betula papyrifera		P	2	3	4	3	2	P	3	4		3		3	4	P	3	2	9
Abies balsamea		P	5*	4*	3*	3*	3*	P*	3*	2*		3*		3	2	P			8
Picea mariana				2		2	2	P	3	3		3			3	P	3	4	7
Thuja occidentalis		P		2	2	2	3	P		2		3							5
Picea glauca					2	2								2	2				3
Populus tremuloides																P			1
Shrubs:																			
Vaccinium membranaceum		P		2	3	2	2	P	3	3		2		2					7
Abies balsamea			3		4	3	2		2			2		2					6
Sorbus decora			2	2	2	2	2		2	2		2		2					6
Amelanchier bartramiana									2	2		2		2			2	2	4
Vaccinium angustifolium				2								2		2			2	2	4
Thuja occidentalis					2	3	2					2							3
Acer spicatum		P														2			2
Betula papyrifera			2									2							2
Diervilla lonicera		P													3	2			2
Vaccinium myrtilloides		P		2															2
Acer rubrum																	2		1
Alnus crispa																2			1
Corylus cornuta		P																	1
Ledum groenlandicum																	3	2	1
Sorbus americana			2																1

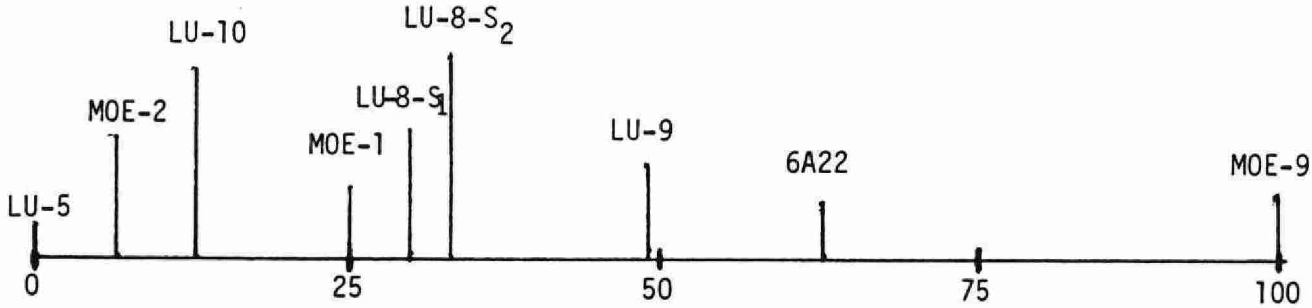
TABLE 8. (Cont'd.)

	LU-8 S_1		LU-8 S_2		LU-5 S_1		MOE-1 S_2		MOE-2 S_2		LU-9 S_1		LU-10 S_1		MOE-9 S_1		6A22 S_2		Presence
	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	
Herbs and Dwarf Shrubs:																			
Cornus canadensis		P	3	3	2		2	P	3	4		2		2	3	2	2		9
Pteridium aquilinum		P	2	3	3	3		2		2		2		2	2		4	3	9
Mianthemum canadense		P	2	2	2		2	P	2	2		2		2			2	2	8
Clintonia borealis		P	2	2			3	P	2	2					2		2	2	6
Lycopodium annotinum		P	3		2	2				2				2					5
Aralia nudicaulis			2						2	2		2			2	2			4
Trientalis borealis			2	2								2		2			2	2	4
Dryopteris austriaca								2						2		2			3
Aster macrophyllus																2			1
Coptis groenlandicum							2												1
Epigaea repens																	2	3	1
Gaultheria procumbens																	2	2	1
Linnaea borealis			2	2															1
Lycopodium lucidulum					2	2													1
Mosses:																			
Pleurozium schreberi			2	1	1			P	1	P		P			1	P	3	2	7
Dicranum ontariense					1		1	P	1								1		4
D. scopanium			1	1					1				1				1		4
D. polysetum							1								1	P	2	2	3
Drapanocladus uncinatus				1					1										2
Calicladium haldanianum															1				1
Hylocomium splendens										P									1
Dicranum montanum					1														1
Liverworts:																			
Bazzania trilobata																	1		1
Lichens:																			
Cladina rangiferina															1		+	1	2
C. mitis																	1		1
C. stellaris																		1	1

trees, 22 shrubs (includes tree regeneration), 21 herbs, 4 dwarf shrubs, 27 mosses, 10 liverworts, and 16 lichens.

Polar Ordination of the Study Sites

The ordination shows six sample areas (LU-8, LU-5, MOE-1, LU-9, and LU-10) to be floristically similar. Site 6A22 is somewhat different from the other areas. Site MOE-9, however, is distinctly different from the other study areas.



5.0 DISCUSSION

5.1 Bedrock and Soil Study

Physical and chemical properties of the Podzolic soils are similar throughout the study area varying only at MOE-9 where the glacio-fluvial sand possesses lower cation exchange capacity. At MOE-9 the soil has been leached to a greater extent by water movement and sorting of particles.

Since the lead accumulation found in the soil surface horizons cannot be explained from the bedrock or soil mineralogy, it is suggested that this accumulation might be as a result of aerial deposition over the past decades. The lead levels found in the soil organic horizons in this study are comparable to levels found in similar soils in areas of higher sulphate

loading such as the Plastic Lake watershed (x65 ug/g) in Dorset, Ontario (Figure 12). Lead from aerial deposition can combine with soil surface organic material to inhibit microbial activity and retard natural decay of organic matter (Tyler, 1975). High lead levels could thus be responsible for the abundance of fibrous woody material found in the soil surface horizons around the study lakes. Lead content in the lake waters was under the 3 ug/L detection limit. Excessive lead values can be found in the top 20 cm of lake bottom sediment as found by Wong and Nriagu (1985) in a study of other Northern Ontario lakes. However, no measurements of lead in lake sediments were completed for this study.

Three of the eight study lakes LU-8, LU-5 and MOE-1 have been determined to be acid lakes with a pH of 5.0 and zero alkalinity (Figure 13). Lake MOE-2 is marginal, fluctuating seasonally with low alkalinity and pH. Lakes LU-9, LU-10, MOE-9 and 6A22 are non-acid but very "sensitive" with low buffering capacity and a total cation summation of less than 200 ueq/L.

In the "sensitive" lakes (LU-9, LU-10, MOE-9 and 6A22) soil parent material-pH seem to trend with lake water-pH and alkalinity but this relationship is not apparent once the lake water is acidified as in LU-8, LU-5 and MOE-1. A similar trend is suggested when calcium and magnesium concentrations in soil and lake water are compared (Figure 14). This relationship is not evident when comparisons are made with soil surface horizons.

5.2 Vegetation Study

The trends in dominant vegetation (Table 8) do not appear to be related to specific soil characteristics such as soil acidity (Table 6). Equally, little apparent relationship is present when the vegetation is compared to lake characteristics (Table 1). With this disclaimer in mind, some generalizations can be made of the vegetation and its relationships to the environment in Pukaskwa Park.

FIGURE 12

LEAD LEVELS IN SOIL ORGANIC HORIZON (LFH) IN ONTARIO

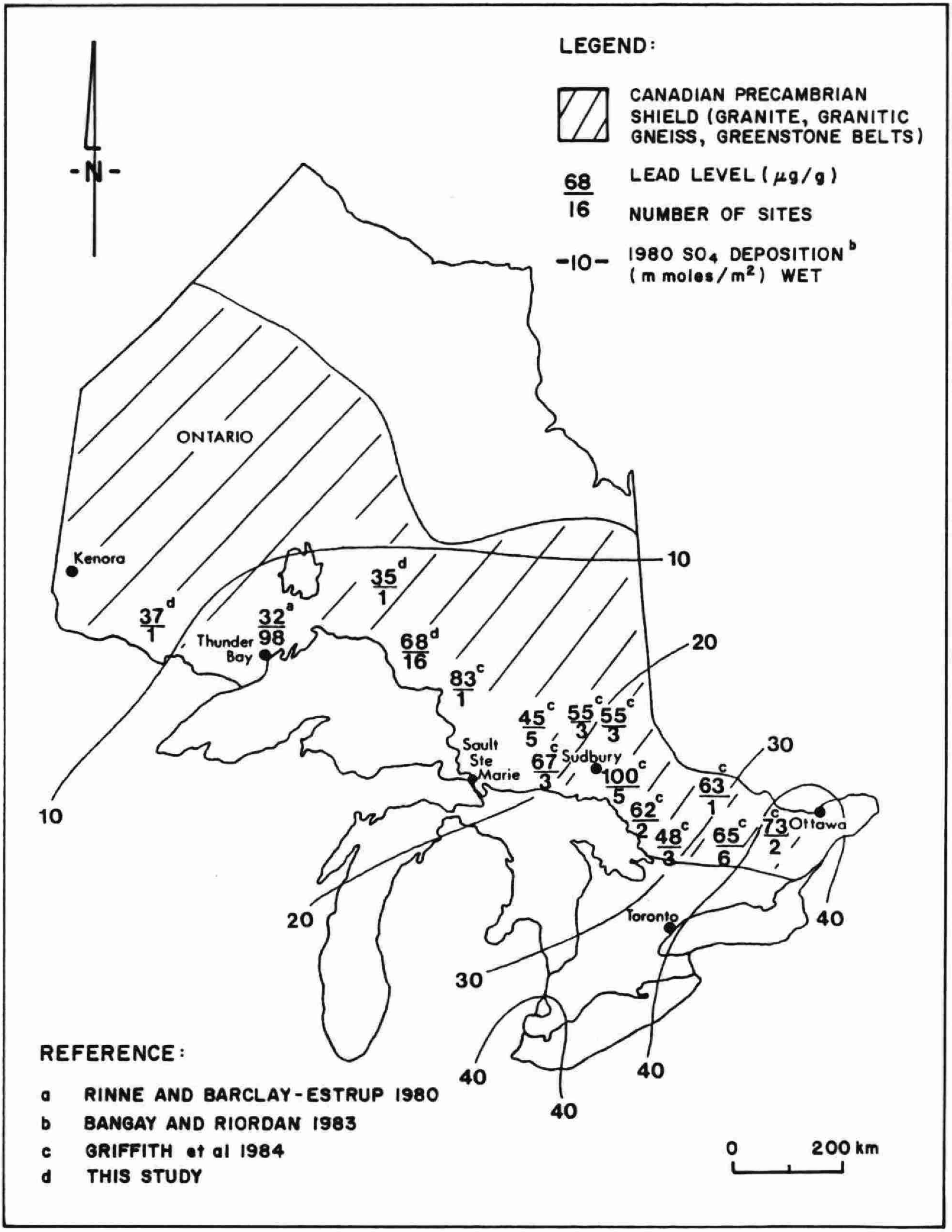


FIGURE 13

COMPARISON OF SOIL pH WITH LAKE pH AND ALKALINTY

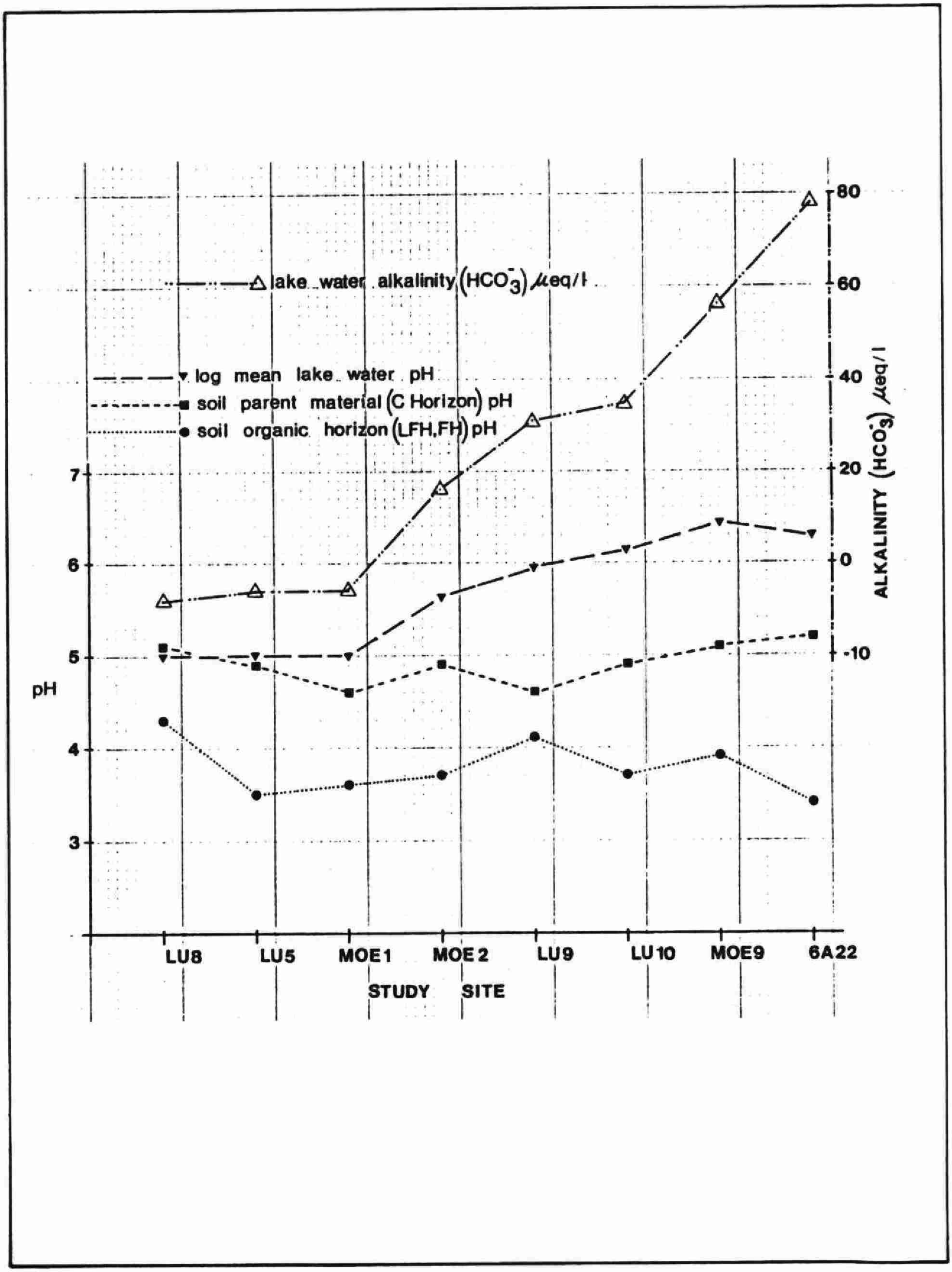
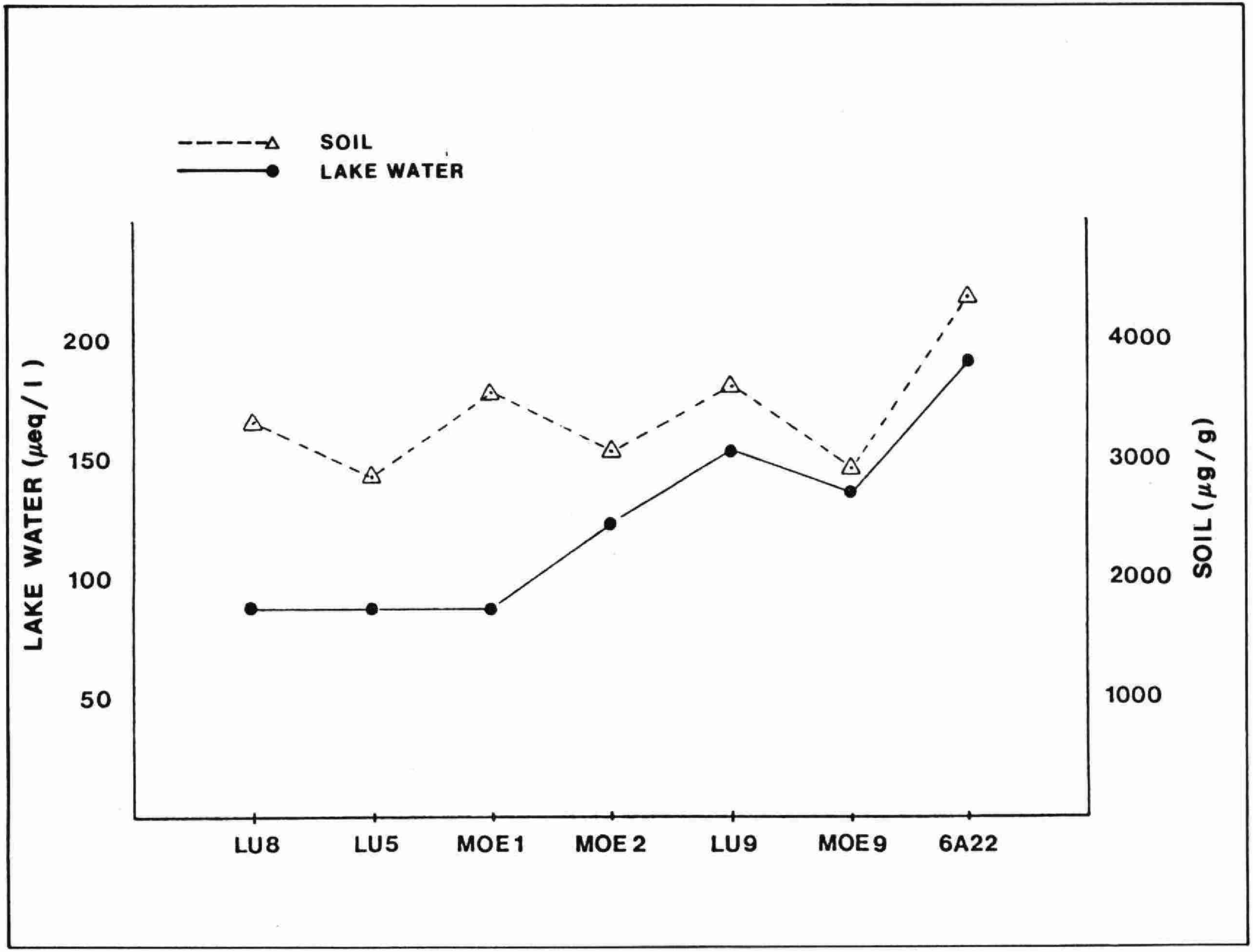


FIGURE 14

CALCIUM AND MAGNESIUM CONCENTRATIONS IN SOIL AND LAKE WATER



According to the polar ordination, the study sites are mostly very similar. Only MOE-9, and to a lesser degree 6A22, are floristically different from the other sites. MOE-9 is on an old burn and is not as old a forest as the other sites, which, at least in part, accounts for its differences. 6A22 is unusual in that it is dominated by black spruce. The reason for this is not obvious but could be historical, if there was a rapid re-invasion after a fire at a time when black spruce seeds were readily available.

The vegetation of the study sites is clearly boreal forest. This is true of all the strata: tree, shrub, herb, bryophyte and lichen. However, all strata also have species that are not typical of the Boreal Forest as a whole. White birch, balsam fir, and black and white spruce are typical Boreal Forest trees. But white cedar is found in only the southern central part of the Boreal Forest. Jack pine and trembling aspen are conspicuously absent or scarce. Labrador tea and mountain alder are typical Boreal Forest shrub species; however, two of the most common shrub species found at Pukaskwa are not typical. Mountain juneberry is found only in the eastern part of the Boreal Forest. Mountain bilberry, which is common in the study area, is a new record for Ontario and is not a Boreal Forest species. It is found primarily in the Coast Forest region of British Columbia and the Sub-Alpine Forest region of Alberta and British Columbia. However, it does occur in the Boreal Forest region of northern Alberta and the southwestern part of the Northwest Territories. It is also found in a small area in Michigan. In the herb and dwarf shrub layer Canada bunchberry, twinflower, and shining club moss are typical boreal species, but bracken fern, blue-bead lily, trailing arbutus, and teaberry are not. In the bryophyte and lichen layer, most of the species, including Pleurozium schreberi, Hylocomium splendens, Ptilidium pulcherrimum, Blepharostoma trichophyllum, Cladina mitis and Cladina rangiferina, are found throughout the boreal forest. But Calicladium haldanianum and Plagiothecium laetum are not typical boreal forest moss species. The Pukaskwa study sites are therefore Boreal Forest with a good component of Great Lakes St. Lawrence Forest species as well. The species lists add one vascular plant, two mosses, two liverworts, and ten lichens to the lists of Garton (1975) and Gimbarzevsky (1978).

The vegetation-soil relationships are obviously complex and, in some cases, based on the available information, rather puzzling. The soils are very acid and of low nutrient status. Most of the species are typical of acidic soils, but there are some apparent anomalies. White cedar is considered to be a tree of neutral or slightly acid soils, yet in the study area it is a common tree, not only near the lake shore where there is a higher pH, but also in very acid soils at LU-5-S_1, and MOE 2-S_2. Also, chokecherry is more typical of higher base status soils.

The mean pH of the precipitation at Pukaskwa is about 4.5 (Chan et al., 1983). This acid rain would be altered by the mixed forest at the study sites. A mixed forest has several layers, and each layer would be involved in ion exchange. Although such a forest would have less buffering capacity than a deciduous forest, it would have more than a pure conifer forest. But regardless of the alteration by the vegetation, it is axiomatic that the more acid the precipitation, the more acid will be the stemflow and throughfall that reaches the soil. The specific relationships cannot be interpreted with the available data. However, a generalization can be made. The low nutrient bedrock, the low-buffering capacity mineral soil, the very acid organic soil, and the cool wet climate produce acidic conditions in soils and lakes. These are aggravated by the increasing acidity of the precipitation. The mature boreal forest communities would buffer the acidic precipitation to some degree, but only further studies, espcially of the vegetation of the non-acidic lakes, will answer the question of what role vegetation plays in the acidification of these lakes.

This study has provided detailed information concerning the vegetation associated with the soil study areas of some acidified lakes in Pukaskwa Park. This information adds to the general knowledge of vegetation in this national park and provides a database for future comparisons and studies in relation to the long range transport of air pollutants.

6.0 SUMMARY AND RECOMMENDATIONS

A study of 39 lakes in Pukaskwa National Park, Ontario, showed some of these lakes to be acid-stressed. So that these lake ecosystems could be better understood, bedrock, soil and vegetation studies were carried out at eight of the acid-stressed lakes from 1983 to 1985.

The bedrock and soil around the eight lakes were classified and their physical and chemical properties documented. Although further investigations are needed, some general trends have been noted. Shallow podzolic soils over granitic bedrock found around the eight lakes contribute to create acid sensitive lake and terrestrial environments. Existing coarse texture, low cation exchange capacity, lack of carbonates and clay offer very little buffering capacity toward neutralizing acidic inputs to the terrestrial system of the area. Iron and aluminum rich soils on steeply dipping shoreline slopes add greater potential for metal-rich leachates to enter the lakes. Leaching of metals from acidic soils can be increased by acidic precipitation. Lead levels in the soil organic horizons are comparable to values found in similar soils in areas of higher sulphate loading and it is suggested that these levels may have resulted from aerial deposition.

The vegetation around the eight lakes is primarily mature Boreal Forest but with a significant component of Great Lakes-St. Lawrence Forest species. Only one lake has a relatively recent fire history, and therefore, a younger forest, with the other seven having mature and overmature forests. An ordination shows all to be similar, except that one lake is floristically rather different. Generally, the Boreal Forest around these lakes would do little to buffer high deposition rates of sulphate. The study vegetation list includes - besides several new records for Pukaskwa National Park - one new species of shrub for Ontario.

Further studies should include studies of non-sensitive areas in Pukaskwa National Park, in addition to studies of sensitive areas, to help define possible interrelationships. Parameters used to measure aquatic and

terrestrial characteristics should be common and could include total element analysis, study of metals in the organically complexed form and the summation of cations and anions in relation to exchange capacities which reflect sensitivity. Lead levels in soil organic horizons require further investigation to determine their origin and effect on the rate of soil organic matter decomposition.

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TABLE 9

List of Abbreviations for Figures, Tables, and Appendices.

Soil Horizons

OM	-	organic (> 17%) medium decomposition
L	-	organic, leaves, twigs, woody material
F	-	organic, partly decomposed
H	-	organic, humus, decomposed
Ae	-	mineral horizon, eluviated of clay, organics, Fe, Al
j	-	thin Ae, variable, indistinct
Bf	-	enriched mineral horizon with organic matter, Fe, Al
BC	-	transitional of B and C material
C	-	parent material, unaltered mineral horizon
R	-	bedrock, lithic contact

Sand Sizes

VCS	-	very coarse sand
CS	-	coarse sand
MS	-	medium sand
FS	-	fine sand
VFS	-	very fine sand

Rock Type

Qrt	-	quartz
Feld	-	feldspar
Qrtz	-	quartzite
Biot	-	biotite mica
Amp	-	amphibolite
Gran	-	granite

Vegetation

Bf	-	balsam fir
Bw	-	white birch
Ce	-	cedar
Po	-	poplar
Pw	-	white pine
S	-	spruce

Sample Sites

S	-	soil sample site O
R	-	rock sample site X

APPENDIX A.

Dominant Trees (woody > 2 metres tall) of the 10 x 10 metre quadrat.
1. d.b.h. of individual trees; 2. Site $\bar{X}$ (mean) d b h

		LU-5 S_2 (cm)	LU-5 S_1 (cm)	MOE-1 S_2 (cm)	MOE-2 S_2 (cm)	LU-9 S_1 (cm)	LU-10 S_1 (cm)	MOE-9 S_1 (cm)	6A22 S_2 (cm)
Betula papyrifera	Tree 1	30.8	34.0	28.0	34.0	32.0	32.0	17.5	15.2
	Tree 2	26.0	30.0	28.0	31.0	31.0	29.4	14.8	14.5
	Tree 3	24.0	28.0	-	15.0	27.0	27.8	8.8	9.8
	Tree 4	20.0	18.4	-	7.6	27.0	24.0	-	9.7
	$\bar{X}$ d.b.h.:	25.2	27.6	28.0	21.9	29.3	28.3	13.7	12.3
Abies balsamea	Tree 1	16.8	3.0	17.8	14.3	15.0	21.0	11.1	-
	Tree 2	14.0	2.0	14.6	6.3	12.5	14.0	5.0	-
	Tree 3	9.2	-	13.8	-	11.0	13.0	1.8	-
	Tree 4	4.0	-	9.0	-	11.0	6.5	1.6	-
	$\bar{X}$ d.b.h.:	11.0	2.5	13.8	10.3	12.4	13.6	4.9	-
Picea mariana	Tree 1	13.1	-	41.8	19.3	22.0	-	7.4	22.0
	Tree 2	7.6	-	-	18.3	11.0	-	6.2	14.0
	Tree 3	6.0	-	-	12.8	7.2	-	5.8	10.5
	Tree 4	3.5	-	-	5.8	6.5	-	5.8	6.0
	$\bar{X}$ d.b.h.:	7.6	-	41.8	14.1	11.7	-	6.3	13.1
Picea glauca	Tree 1	14.0	2.5	-	-	-	24.0	12.5	-
	Tree 2	12.5	-	-	-	-	13.6	11.1	-
	Tree 3	9.4	-	-	-	-	10.4	7.0	-
	Tree 4	9.0	-	-	-	-	6.0	4.9	-
	$\bar{X}$ d.b.h.:	11.2	2.5	-	-	-	13.5	8.9	-
Thuja occidentalis	Tree 1	-	5.0	34.2	-	40.0	-	-	-
	Tree 2	-	3.5	24.5	-	25.0	-	-	-
	Tree 3	-	1.8	15.8	-	7.2	-	-	-
	Tree 4	-	-	7.5	-	6.5	-	-	-
	$\bar{X}$ d.b.h.:	-	3.4	20.5	-	19.7	-	-	-
$\bar{X}$ dbh of all species		9.0	12.8	21.4	16.4	18.2	18.5	8.1	12.7

APPENDIX B. Species List of Plants (Vascular, Bryophyte, and Lichen) found at APIOS Study Sites in Pukaskwa National Park. S = Soil Pit 10 x 10 m quadrat. G = General area around the quadrat. X = present but no cover estimate. Braun-Blanquet Cover Scale: + = < 1%; 1 = 1-5%; 2 = 6-25%; 3 = 26=50%; 4 = 51=74%; 5 = 76-100%.

	LU-8		LU-8		LU-5		MOE-1		MOE-2		LU-9		LU-10		MOE-9		6A-22		Presence
TREES (woody and > 2 m)	S_1	G	S_2	G	S_1	G	S_2	G	S_2	G	S_1	G	S_1	G	S_1	G	S_2	G	
Betula papyrifera		X	2	3	4	3	2	X	3	4		3		3	4	X	3	2	9
Abies balsamea		X	5*	4*	3*	3*	3*	X*	3*	2*		3*		3	1	X			8
Picea mariana				1		2	2	X	3	3		3			3	X	3	4	7
P. glauca		X		1	2	2						1		2	2	X			6
Thuja occidentalis		X	+	2	2	2	3	X		2		3							6
Sorbus decora		X										1						X	3
Acer rubrum												1				X			2
Pinus strobus								X											1
Populus tremuloides																X			1
Larix laricina																		1	1
SHRUBS: (woody < 2 m)																			
Amelanchier bartramiana		X		X	1			X	2	2		2		2	+		2	2	9
Sorbus decora			2	2	2	2	2		2	2		2		2			1		7
Abies balsamea			3		4	3	2		2			2		2				X	7
Vaccinium membranaceum		X		2	3	2	2	X	3	3		2		2					7
Acer spicatum		X		X				X		X				1		1			6
Taxus canadensis			1		+	X		X		X		X							5
Vaccinium angustifolium				2								2		2		X	2	2	5
V. myrtilloides		X	+	2					1						+		+		5
Thuja occidentalis					2	3	2					2				X			4
Acer rubrum												1				X	2		3
Picea mariana			1		1									X					3

SHRUBS (Cont'd.)	S_1	G	S_2	G	S_1	G	S_2	G	S_2	G	S_1	G	S_1	G	S_1	G	S_2	G	
Betula papyrifera			2									2							2
Diervilla lonicera		X													3	2			2
Alnus crispa																2			1
Chamaedaphne calyculata																		X	1
Corylus cornuta		X																	1
Ledum groenlandicum																	3	2	1
Picea glauca			1																1
Prunus pensylvanica															1				1
P. virginiana				X															1
Salix humilis															1				1
Sorbus americana			1																1
HERBS AND DWARF SHRUBS:																			
Clintonia borealis		X	2	2	1		3	X	2	2		1		1	2		2	2	9
Cornus canadensis		X	3	3	2		2	X	3	4		2		2	3	2	2		9
Pteridium aquilinum		X	2	3	3	3		2	1	2		2		2	2		4	3	9
Dryopteris austriaca		X		X	1	X		2	1			1		2		2			8
Maianthemum canadense		X	2	2	2		2	X	2	2		2		2			2	2	8
Trientalis borealis		X	2	2	+		+		1			2		2			2	2	8
Aralia nudicaulis		X	2				1		2	2		2		X	2	2			7
Coptis groenlandica				X	1		2	1	1			1		X			1		7
Lycopodium annotinum		X	3		2	2		X	1	2		X		2					7
L. obscurum		X	+			X						X		1		+		X	7
Gaultheria hispidula			+		+		+			X							1	1	5
Osmunda claytoniana				X	+							X		X		1			5
Cypripedium acaule				X	+		+												3
Epigaea repens						X						X					2	3	3

HERBS AND DWARF SHRUBS (Cont'd.)

	S_1	G	S_2	G	S_1	G	S_2	G	S_2	G	S_1	G	S_1	G	S_1	G	S_2	G	
Goodyera tesselata							+					X			+				3
Linnaea borealis			2	2		X								X					3
Lycopodium clavatum			+					X								+			3
L. lucidulum					2	2						X							2
Aster macrophyllus																2			1
Carex arctata				X															1
Gaultheria procumbens																	2	2	1
Goodyera repens															+				1
Lycopodium complanatum														X					1
Streptopus roseus												X							1
S. amplexifolius				X															1

MOSSES:

	S_1	G	S_2	G	S_1	G	S_2	G	S_2	G	S_1	G	S_1	G	S_1	G	S_2	G	
Dicranum montanum		X	+	X	1		+			X		+		X	1	X	+		9
Pleurozium schreberi		X	2	1	1		+	X	1	X		+		X	1	+	3	2	9
Dicranum ontariense			+		1		1	X	1					X	+		1		7
D. scoparium			1	1		X	+		1			+		1			1		7
Drepanocladus uncinatus		X	1		+	X		X	1			X		X					7
Ptilium crista-castrensis					+		+			X		X		X		+	+		7
Pogonatum alpinum		X		X				Z	+			X		X					6
Polytrichum juniperinum		X	+				+					X		X		+			6
Plagiothecium laetum			+		+			X				X		X					5
Pohlia nutans			+		+			X	+							X			5
Dicranum polysetum							1								1	+	2	2	3
Hylocomium splendens										X		+				+			3
Pylaisiadelpha recurvans					+				+								+		3
Sphagnum russowii					+											X	+		3

MOSSES (Cont'd.)	S_1	G	S_2	G	S_1	G	S_2	G	S_2	G	S_1	G	S_1	G	S_1	G	S_2	G	
Brachythecium reflexum			+		X														2
Hylocomium umbratum					X							X							2
Brachythecium curtum												X							1
Brachythecium sp.			+																1
Callicladium haldanianum															1				1
Dicranum flagellare															+	X			1
D. fuscescens																X			1
Hypnum pallescens																X			1
Plagiomnium cuspidatum			+																1
Paraleucobryum longifolium								X											1
Thuidium abietinum					+														1
Sphagnum sp.												X							1
Splachhum luteum												X							1
LIVERWORTS																			
Ptilidium pulcherrimum		X	+		+		+			X		X		X	+				8
Barbilophozia attenuata			+		+		+					X		X			+		6
Blepharostoma trichophyllus					+		+					X		X					4
Bazzania trilobata					+							X					1	X	3
Barbilophozia hatcheri		X	+		+														2
Jamesoniella autumnalis					+										+				2
Ptilidium ciliare															+	+	+		2
Cephalozia lunulifolia												X							1
Lepidozia reptans																	+		1
Lophozia porphyroleuca (*Lophozia guttulata*)					+														1

Cont'd.)	S_1	G	S_2	G	S_1	G	S_2	G	S_2	G	S_1	G	S_1	G	S_1	G	S_2	G	
LICHENS																			
<u>Cladonia</u> <u>coniocraea</u>		X	+	X	+		+		+			X		X	+		+		9
<u>C.</u> <u>chlorophaea</u>		X	+		+	X	+		+			X		X		+	X		8
<u>Cladina</u> <u>rangiferina</u>		X		X			+			X					1	+	+	1	6
<u>Cladonia</u> <u>squamosa</u>		X		X			+					X							4
<u>C.</u> <u>cenotea</u>					+				+						+				3
<u>C.</u> <u>phyllophora</u>				X										X	+				3
<u>Cetraria</u> <u>pinastri</u>			+	X		X			+										3
<u>Cladonia</u> <u>amaurocraea</u>																		X	1
<u>Cladina</u> <u>mitis</u>																		1	1
<u>C.</u> <u>stellaris</u>																		1	1
<u>Cladonia</u> <u>conista</u>							+												1
<u>C.</u> <u>digitata</u>																	+		1
<u>C.</u> <u>uncialis</u>																	+		1
<u>Hypogymnia</u> <u>physodes</u>				X															1
<u>Lecidea</u> <u>berengeriana</u>				X															1
<u>Peltigera</u> <u>aphthosa</u>												X							1

APPENDIX C

SOIL DATA REPORT.

PHEW	-	pH in water
PHECA	-	pH in 0.01 M $Ca\ Cl_2$
%GRAVEL	-	weight of ≥ 2 mm material expressed as % of total sample
SAND	-	% weight of 2 mm to 53 µm material
SILT	-	% weight of 53 µm to 2 µm material
CLAY	-	% weight of ≤ 2 µm material
CAESC	-	Calcium, exchangeable, NaCl extracted, µg/g dry as Ca
MGESC	-	Magnesium, exchangeable, NaCl extracted, µg/g dry as Mg
KKESC	-	Potassium, exchangeable, NaCl extracted, µg/g dry as K
ALESC	-	Aluminum, exchangeable, NaCl extracted, µg/g dry as Al
CEC	-	Cation exchange capacity, meq/100 g
ALECA	-	Aluminum, $CaCl_2$ extracted, µg/g dry as Al
FEEPY	-	Iron, Na-pyrophosphate extracted, % dry weight as Fe
ALEPY	-	Aluminum, Na-pyrophosphate extracted, % dry weight as Al
MNEPY	-	Manganese, N-pyrophosphate extracted, % dry weight as Mn
FEEDI	-	Iron, Dithionite extracted, % dry weight as Fe
ALEDI	-	Aluminum, Dithionite extracted, % dry weight as Al
MNEDI	-	Manganese, Dithionite extracted, % dry weight as Mn
SS04	-	Sulphate, water extracted, µg/g dry as S
NNTK	-	Nitrogen, total Kjeldahl, unfiltered reactive, mg/g as N
COD	-	Organic carbon, % dry weight
CUUT	-	Copper, unfiltered total, µg/g dry as Cu
NIUT	-	Nickel, unfiltered total, µg/g dry as Ni
PBUT	-	Lead, unfiltered total, µg/g dry as Pb
ZINC or ZNUT	-	Zinc, unfiltered total, µg/g dry as Zn

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001262-LU-8-S1									
	29033-LFH	830725	4.2	3.70	0.0	0.0	0.0	0.0	2600.00
	29034-AE	830725	4.2	3.30	40.00	60.00	37.00	4.00	79.00
	29035-BF	830725	4.9	4.30	53.30	77.00	19.00	3.00	140.00
	29036-BC	830725	5.5	4.70	40.20	79.00	21.00	.50	61.00
	29037-C	830725	5.3	4.60	34.20	90.00	10.00	.50	33.00
MEAN			4.82	4.120	33.5400	61.200	17.400	1.6000	582.600
STDEV			.606	.6017	20.0119	35.857	13.759	1.7819	1128.44

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001262-LU-8-S1								
	29033-LFH	830725	390.00	1300.0	21.00	19.00	6.600	.018
	29034-AE	830725	13.00	48.00	170.00	2.30	17.000	-9.000
	29035-BF	830725	10.00	25.00	96.00	1.80	9.800	.660
	29036-BC	830725	3.00	16.00	14.00	.51	2.000	.120
	29037-C	830725	2.00	13.00	25.00	.47	3.900	.065
MEAN			83.6000	280.40	65.200	4.8160	7.86000	.21575
STDEV			171.3456	570.14	67.310	7.9693	5.89305	.29909

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001262-LU-8-S1								
	29033-LFH	830725	.029	.0690	.130	.033	.0720	280.00
	29034-AE	830725	-9.000	-9.0000	-9.000	-9.000	-9.0000	12.00
	29035-BF	830725	.630	.0052	1.000	.790	.0170	5.50
	29036-BC	830725	.270	.0015	.240	.300	.0041	6.50
	29037-C	830725	.230	.0017	.170	.220	.0033	8.10
MEAN			.28975	.019350	.38500	.33575	.024100	62.420
STDEV			.25015	.033144	.41251	.32284	.032545	121.66

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001262-LU-8-S1								
	29033-LFH	830725	16.80	46.60	18.0000	4.300	69.000	140.000
	29034-AE	830725	1.10	-9.00	-9.0000	-9.000	-9.000	-9.000
	29035-BF	830725	1.40	2.70	7.7000	5.200	3.000	37.000
	29036-BC	830725	.30	.70	5.4000	10.000	1.500	32.000
	29037-C	830725	.40	.70	6.5000	7.900	1.500	23.000
MEAN			4.000	12.675	9.40000	6.85000	18.7500	58.0000
STDEV			7.170	22.636	5.80976	2.59808	33.5075	54.9727

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001273-LU-8-S3									
	29082-OM	830725	4.5	4.00	9.80	75.00	15.00	9.00	550.00
	29083-C	830725	5.5	5.10	9.80	91.00	9.00	1.00	240.00
MEAN			5.00	4.550	9.8000	83.000	12.000	5.0000	395.000
STDEV			.707	.7778	0.0	11.314	4.2426	5.6569	219.203

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001273-LU-8-S3								
	29082-OM	830725	48.00	31.00	180.00	5.00	14.000	.042
	29083-C	830725	31.00	2.00	2.50	1.50	.920	.015
MEAN			39.5000	16.500	91.250	3.2500	7.46000	.02850
STDEV			12.0208	20.506	125.51	2.4749	9.24896	.01909

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001273-LU-8-S3								
	29082-OM	830725	.310	.0003	.059	.360	.0009	130.00
	29083-C	830725	.043	0.0	.049	.043	.0009	250.00
MEAN			.17650	.000150	.05400	.20150	.000900	190.00
STDEV			.18880	.000212	.00707	.22415	0.0	84.853

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001273-LU-8-S3								
	29082-OM	830725	3.20	12.20	22.0000	7.300	3.700	18.000
	29083-C	830725	.30	2.60	20.0000	5.900	1.500	12.000
MEAN			1.750	7.4000	21.0000	6.60000	2.60000	15.0000
STDEV			2.051	6.7882	1.41421	.98995	1.55563	4.24264

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001264-LU-5-S1									
	29043-LFH	830726	3.9	2.90	0.0	0.0	0.0	0.0	2400.00
	29044-AEJ	830726	4.2	3.30	29.30	52.00	43.00	4.00	54.00
	29045-BF1	830726	4.6	4.20	18.30	63.00	32.00	5.00	43.00
	29046-BF2	830726	4.9	4.20	30.90	61.00	34.00	5.00	61.00
	29047-C	830726	5.1	4.50	17.70	64.00	33.00	3.00	15.00
MEAN			4.54	3.820	19.2400	48.000	28.400	3.4000	514.600
STDEV			.493	.6834	12.3551	27.249	16.471	2.0736	1054.12

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001264-LU-5-S1								
	29043-LFH	830726	290.00	580.00	170.00	17.00	12.000	.063
	29044-AEJ	830726	7.00	25.00	240.00	2.70	34.000	.160
	29045-BF1	830726	3.00	14.00	110.00	1.40	23.000	.550
	29046-BF2	830726	5.00	16.00	86.00	1.20	22.000	.360
	29047-C	830726	2.00	11.00	29.00	.41	7.500	.130
MEAN			61.4000	129.20	127.00	4.5420	19.7000	.25260
STDEV			127.8057	252.06	80.920	7.0127	10.3537	.19971

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001264-LU-5-S1								
	29043-LFH	830726	.099	.0060	.180	.100	.0067	95.00
	29044-AEJ	830726	.110	.0002	.250	.110	.0008	9.10
	29045-BF1	830726	1.000	.0003	.700	1.100	.0010	8.90
	29046-BF2	830726	.890	.0004	.470	.880	.0017	5.40
	29047-C	830726	.350	.0008	.300	.360	.0061	6.30
MEAN			.48980	.001540	.38000	.51000	.003260	24.940
STDEV			.42924	.002504	.20845	.45706	.002894	39.198

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001264-LU-5-S1								
	29043-LFH	830726	10.80	38.50	9.5000	4.600	61.000	66.000
	29044-AEJ	830726	.80	1.90	5.0000	1.000	3.600	4.500
	29045-BF1	830726	1.80	4.40	7.0000	7.100	3.000	11.000
	29046-BF2	830726	1.20	2.90	6.0000	10.000	1.500	16.000
	29047-C	830726	.30	1.10	6.0000	9.000	1.500	12.000
MEAN			2.980	9.7600	6.70000	6.34000	14.1200	21.9000
STDEV			4.406	16.113	1.71756	3.62602	26.2230	24.9960

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001265-LU-5-S2									
	29048-LFH	830726	3.9	3.40	0.0	-9.00	-9.00	-9.00	2400.00
	29049-AEJ	830726	4.5	3.40	38.40	30.00	61.00	9.00	220.00
	29050-BF1	830726	4.6	4.30	10.70	60.00	30.00	10.00	43.00
	29051-BF2	830726	4.5	4.20	10.40	71.00	21.00	8.00	41.00
	29052-BC	830726	4.7	4.30	35.20	69.00	23.00	8.00	43.00
MEAN			4.44	3.920	18.9400	57.500	33.750	8.7500	549.400
STDEV			.313	.4764	16.9014	18.947	18.572	.9574	1037.37

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001265-LU-5-S2								
	29048-LFH	830726	190.00	1100.0	130.00	17.00	29.000	-9.000
	29049-AEJ	830726	16.00	65.00	260.00	4.00	20.000	.460
	29050-BF1	830726	4.00	26.00	130.00	1.60	15.000	1.100
	29051-BF2	830726	4.00	18.00	170.00	1.90	21.000	1.800
	29052-BC	830726	9.00	17.00	98.00	1.30	15.000	1.190
MEAN			44.6000	245.20	157.60	5.1600	20.0000	1.1375
STDEV			81.4297	478.25	62.680	6.7032	5.74456	.54835

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001265-LU-5-S2								
	29048-LFH	830726	-9.000	-9.0000	-9.000	-9.000	-9.0000	410.00
	29049-AEJ	830726	.140	.0001	.780	.180	.0008	20.00
	29050-BF1	830726	1.600	.0003	2.200	2.300	.0015	19.00
	29051-BF2	830726	1.700	.0001	2.700	2.100	.0017	17.00
	29052-BC	830726	1.500	.0001	1.500	1.900	.0008	25.00
MEAN			1.2350	.000150	1.7950	1.6200	.001200	98.200
STDEV			.73455	.000100	.83672	.97379	.000469	174.33

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001265-LU-5-S2								
	29048-LFH	830726	13.80	-9.00	-9.0000	-9.000	-9.000	-9.000
	29049-AEJ	830726	1.50	5.00	18.0000	1.000	13.000	12.000
	29050-BF1	830726	1.80	3.60	8.5000	2.400	20.000	15.000
	29051-BF2	830726	1.60	6.20	11.0000	2.200	20.000	18.000
	29052-BC	830726	1.40	5.40	14.0000	4.300	16.000	22.000
MEAN			4.020	5.0500	12.8750	2.47500	17.2500	16.7500
STDEV			5.469	1.0878	4.09013	1.36473	3.40343	4.27200

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001274-LU-5-S3									
	29084-OM1	830726	4.1	3.80	0.0	54.00	33.00	13.00	230.00
	29085-OM2	830726	5.2	4.60	7.40	57.00	36.00	7.00	1200.00
MEAN			4.65	4.200	3.7000	55.500	34.500	10.000	715.000
STDEV			.778	.5657	5.2326	2.1213	2.1213	4.2426	685.894

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001274-LU-5-S3								
	29084-OM1	830726	23.00	41.00	250.00	3.90	41.000	.045
	29085-OM2	830726	83.00	14.00	30.00	7.20	2.100	.067
MEAN			53.0000	27.500	140.00	5.5500	21.5500	.05600
STDEV			42.4264	19.092	155.56	2.3335	27.5065	.01556

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001274-LU-5-S3								
	29084-OM1	830726	.460	.0002	.083	.430	.0004	29.00
	29085-OM2	830726	.280	0.0	.110	.320	.0002	98.00
MEAN			.37000	.000100	.09650	.37500	.000300	63.500
STDEV			.12728	.000141	.01909	.07778	.000141	48.790

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001274-LU-5-S3								
	29084-OM1	830726	4.20	6.70	3.6000	6.500	12.000	16.000
	29085-OM2	830726	3.10	7.30	17.0000	8.600	3.100	17.000
MEAN			3.650	7.0000	10.3000	7.55000	7.55000	16.5000
STDEV			.7778	.4243	9.47523	1.48492	6.29325	.70711

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001259-MOE-1-S1									
	29018-LFH	830727	3.8	3.00	0.0	0.0	0.0	0.0	3000.00
	29019-AEJ	830727	4.1	3.30	25.10	57.00	39.00	4.00	66.00
	29020-BF1	830727	4.7	4.10	53.80	64.00	24.00	12.00	69.00
	29021-BF2	830727	4.6	4.10	50.80	54.00	34.00	12.00	79.00
MEAN			4.30	3.625	32.4250	43.750	24.250	7.0000	803.500
STDEV			.424	.5620	25.1632	29.466	17.328	6.0000	1464.34

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001259-MOE-1-S1								
	29018-LFH	830727	380.00	750.00	260.00	22.00	19.000	.100
	29019-AEJ	830727	14.00	51.00	300.00	3.60	30.000	.130
	29020-BF1	830727	9.00	47.00	240.00	3.00	27.000	.620
	29021-BF2	830727	12.00	35.00	370.00	4.30	32.000	.870
MEAN			103.7500	220.75	292.50	8.2250	27.0000	.43000
STDEV			184.1781	352.90	57.373	9.1987	5.71548	.37798

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001259-MOE-1-S1								
	29018-LFH	830727	.140	.0050	.240	.150	.0067	110.00
	29019-AEJ	830727	.093	0.0	.350	.097	.0010	8.90
	29020-BF1	830727	1.400	.0003	1.800	1.700	.0017	12.00
	29021-BF2	830727	1.500	.0001	1.900	2.000	.0013	11.00
MEAN			.78325	.001350	1.0725	.98675	.002675	35.475
STDEV			.77122	.002437	.89983	1.0045	.002699	49.700

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001259-MOE-1-S1								
	29018-LFH	830727	12.50	43.00	10.0000	5.500	89.000	83.000
	29019-AEJ	830727	.60	1.40	3.7000	1.000	1.500	7.000
	29020-BF1	830727	2.50	7.40	10.0000	5.200	7.100	22.000
	29021-BF2	830727	3.10	9.10	12.0000	6.500	9.500	20.000
MEAN			4.675	15.225	8.92500	4.55000	26.7750	33.0000
STDEV			5.324	18.809	3.60867	2.43105	41.6185	33.9902

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001261-MOE-1-S2									
	29027-LFH	830727	3.8	3.20	0.0	0.0	0.0	0.0	2900.00
	29028-AEJ	830727	4.1	3.40	3.30	24.00	70.00	5.00	54.00
	29029-BF1	830727	4.5	3.90	14.20	63.00	29.00	8.00	69.00
	29030-BF2	830727	4.7	4.30	21.40	89.00	9.00	2.00	28.00
	29031-BC	830727	4.8	4.40	27.20	73.00	26.00	1.00	28.00
	29032-C	830727	4.8	4.40	43.30	84.00	16.00	1.50	31.00
MEAN			4.45	3.933	18.2333	55.500	25.000	2.9167	518.333
STDEV			.414	.5279	16.0654	35.692	24.511	3.0069	1166.89

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001261-MOE-1-S2								
	29027-LFH	830727	320.00	600.00	480.00	23.00	17.000	.130
	29028-AEJ	830727	12.00	53.00	430.00	4.80	46.000	.320
	29029-BF1	830727	11.00	41.00	380.00	4.30	40.000	1.300
	29030-BF2	830727	3.00	14.00	120.00	1.40	20.000	.550
	29031-BC	830727	.50	13.00	68.00	.87	10.000	.140
	29032-C	830727	5.00	11.00	62.00	.84	7.600	.069
MEAN			58.5833	122.00	256.67	5.8683	23.4333	.41817
STDEV			128.1462	234.81	193.55	8.5712	15.9250	.46626

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001261-MOE-1-S2								
	29027-LFH	830727	.220	.0170	.240	.180	.0200	120.00
	29028-AEJ	830727	.150	.0003	.530	.160	.0008	13.00
	29029-BF1	830727	1.000	.0007	1.600	1.000	.0023	16.00
	29030-BF2	830727	.810	.0002	.760	.880	.0013	8.80
	29031-BC	830727	.580	.0001	.340	.580	.0010	10.00
	29032-C	830727	.260	.0001	.340	.300	.0015	9.50
MEAN			.50333	.003067	.63500	.51667	.004483	29.550
STDEV			.34955	.006830	.50753	.36253	.007619	44.393

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001261-MOE-1-S2								
	29027-LFH	830727	12.80	39.60	12.0000	5.600	62.000	69.000
	29028-AEJ	830727	.90	2.50	4.7000	2.500	4.200	10.000
	29029-BF1	830727	2.20	5.60	9.7000	4.400	4.400	15.000
	29030-BF2	830727	1.00	3.80	6.2000	4.700	1.500	11.000
	29031-BC	830727	.70	1.90	8.2000	6.100	1.500	11.000
	29032-C	830727	.30	.80	8.7000	8.000	1.500	17.000
MEAN			2.983	9.0333	8.25000	5.21667	12.5167	22.1667
STDEV			4.851	15.066	2.57585	1.84328	24.2806	23.1034

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001271-MOE-2-S1	29071-H	830726	3.4	2.80	0.0	0.0	0.0	0.0	1700.00
	29072-AE	830726	4.3	3.30	21.80	47.00	48.00	4.00	31.00
	29073-BF	830726	4.6	4.00	32.50	56.00	33.00	11.00	31.00
	29074-BC	830726	4.6	4.50	30.50	44.00	53.00	3.00	1.50
	29075-C	830726	4.9	4.80	18.70	55.00	43.00	2.00	4.00
MEAN			4.36	3.880	20.7000	40.400	35.400	4.0000	353.500
STDEV			.577	.8289	12.9323	23.158	21.126	4.1833	752.849

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001271-MOE-2-S1	29071-H	830726	400.00	600.00	360.00	17.00	22.000	.100
	29072-AE	830726	10.00	18.00	270.00	2.90	29.000	.190
	29073-BF	830726	6.00	22.00	240.00	2.70	37.000	.700
	29074-BC	830726	1.00	9.00	28.00	.32	5.700	.190
	29075-C	830726	.50	3.00	10.00	.13	2.300	.065
MEAN			83.5000	130.40	181.60	4.6100	19.2000	.24900
STDEV			176.9717	262.62	154.99	7.0455	14.9045	.25808

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SS04
6001271-MOE-2-S1	29071-H	830726	.160	.0062	.220	.180	.0077	180.00
	29072-AE	830726	.091	0.0	.280	.140	.0006	12.00
	29073-BF	830726	1.200	.0001	1.200	1.600	.0013	25.00
	29074-BC	830726	.370	.0002	.580	.540	.0013	18.00
	29075-C	830726	.190	0.0	.300	.210	.0014	16.00
MEAN			.40220	.001300	.51600	.53400	.002460	50.200
STDEV			.45773	.002740	.40679	.61683	.002947	72.713

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001271-MOE-2-S1	29071-H	830726	9.50	40.30	14.0000	4.900	79.000	120.000
	29072-AE	830726	.80	2.20	10.0000	1.000	3.700	7.700
	29073-BF	830726	1.60	7.10	8.5000	3.900	6.600	14.000
	29074-BC	830726	.70	1.90	9.0000	7.900	6.100	16.000
	29075-C	830726	.40	.60	6.0000	5.900	1.500	12.000
MEAN			2.600	10.420	9.50000	4.72000	19.3800	33.9400
STDEV			3.883	16.885	2.91548	2.55186	33.3908	48.2070

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001266-MOE-2-S2									
	29053-LFH	830726	3.9	3.10	0.0	0.0	0.0	0.0	3200.00
	29054-AE	830726	4.3	3.20	7.60	52.00	42.00	5.00	200.00
	29055-BF1	830726	4.3	3.70	12.00	56.00	35.00	9.00	220.00
MEAN			4.17	3.333	6.5333	36.000	25.667	4.6667	1206.67
STDEV			.231	.3215	6.0707	31.241	22.502	4.5092	1726.31

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001266-MOE-2-S2								
	29053-LFH	830726	280.00	520.00	96.00	21.00	26.000	.039
	29054-AE	830726	17.00	28.00	220.00	3.40	11.000	.140
	29055-BF1	830726	14.00	24.00	360.00	4.80	35.000	.820
MEAN			103.6667	190.67	225.33	9.7333	24.0000	.33300
STDEV			152.7165	285.22	132.08	9.7823	12.1244	.42477

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001266-MOE-2-S2								
	29053-LFH	830726	.078	.0074	.140	.082	.0086	170.00
	29054-AE	830726	.083	.0004	.290	.085	.0013	11.00
	29055-BF1	830726	.400	.0003	1.200	.400	.0008	12.00
MEAN			.18700	.002700	.54333	.18900	.003567	64.333
STDEV			.18448	.004071	.57361	.18274	.004366	91.511

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001266-MOE-2-S2								
	29053-LFH	830726	13.00	31.20	10.0000	3.800	58.000	53.000
	29054-AE	830726	.70	2.70	10.0000	3.800	4.300	9.000
	29055-BF1	830726	1.30	3.70	9.0000	2.800	4.400	13.000
MEAN			5.000	12.533	9.66667	3.46667	22.2333	25.0000
STDEV			6.935	16.174	.577350	.57735	30.9749	24.3311

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001267-LU-9-S1									
	29056-LFH	830726	4.2	3.40	0.0	0.0	0.0	0.0	2700.00
	29057-AE	830726	4.5	3.60	17.30	44.00	50.00	6.00	45.00
	29058-BC	830726	4.5	4.20	13.70	63.00	34.00	3.00	35.00
MEAN			4.40	3.733	10.3333	35.667	28.000	3.0000	926.667
STDEV			.173	.4163	9.1282	32.316	25.534	3.0000	1535.76

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001267-LU-9-S1								
	29056-LFH	830726	280.00	840.00	180.00	20.00	13.000	.057
	29057-AE	830726	8.00	42.00	260.00	3.00	32.000	.170
	29058-BC	830726	3.00	18.00	140.00	1.60	21.000	.490
MEAN			97.0000	300.00	193.33	8.2000	22.0000	.23900
STDEV			158.5024	467.81	61.101	10.243	9.53939	.22460

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001267-LU-9-S1								
	29056-LFH	830726	.150	.0099	.200	.160	.0120	180.00
	29057-AE	830726	.140	.0002	.290	.140	.0040	14.00
	29058-BC	830726	.930	.0001	1.000	1.300	.0013	7.40
MEAN			.40667	.003400	.49667	.53333	.005767	67.133
STDEV			.45325	.005629	.43822	.66403	.005564	97.801

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001267-LU-9-S1								
	29056-LFH	830726	11.20	39.80	11.0000	4.800	97.000	95.000
	29057-AE	830726	1.00	4.00	7.5000	1.000	6.600	9.000
	29058-BC	830726	1.40	3.60	10.0000	4.100	1.500	12.000
MEAN			4.533	15.800	9.50000	3.30000	35.0333	38.6667
STDEV			5.777	20.786	1.80278	2.02237	53.7253	48.8092

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001268-LU-9-S2	29059-LFH	830726	4.1	3.50	0.0	0.0	0.0	0.0	3700.00
	29060-AEJ	830726	4.5	3.60	7.90	32.00	62.00	6.00	65.00
	29061-BC	830726	4.5	4.20	43.10	59.00	37.00	4.00	27.00
MEAN			4.37	3.767	17.0000	30.333	33.000	3.3333	1264.00
STDEV			.231	.3786	22.9458	29.535	31.193	3.0551	2109.72

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001268-LU-9-S2	29059-LFH	830726	340.00	510.00	48.00	23.00	11.000	.048
	29060-AEJ	830726	9.00	29.00	220.00	2.70	29.000	.260
	29061-BC	830726	3.00	10.00	110.00	1.20	18.000	.950
MEAN			117.3333	183.00	126.00	8.9667	19.3333	.41933
STDEV			192.8583	283.35	87.109	12.176	9.07377	.47164

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001268-LU-9-S2	29059-LFH	830726	.079	.0270	.150	.079	.0300	150.00
	29060-AEJ	830726	.150	.0003	.370	.150	.0008	13.00
	29061-BC	830726	.710	.0006	1.400	.760	.0025	12.00
MEAN			.31300	.009300	.64000	.32967	.011100	58.333
STDEV			.34564	.015329	.66731	.37437	.016390	79.387

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001268-LU-9-S2	29059-LFH	830726	10.20	45.50	12.0000	3.600	62.000	270.000
	29060-AEJ	830726	1.10	2.40	7.5000	2.000	8.000	10.000
	29061-BC	830726	.90	2.80	5.5000	1.000	4.300	12.000
MEAN			4.067	16.900	8.33333	2.20000	24.7667	97.3333
STDEV			5.313	24.769	3.32916	1.31149	32.2980	149.537

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001263-LU-10-S1									
	29038-LFH	830725	4.0	3.10	0.0	0.0	0.0	0.0	3100.00
	29039-AE	830725	4.1	3.20	26.30	62.00	37.00	1.00	46.00
	29040-BF	830725	4.7	4.20	25.10	72.00	24.00	4.00	69.00
	29041-BC	830725	4.8	4.30	20.40	79.00	18.00	3.00	33.00
	29042-C	830725	4.9	4.40	18.10	82.00	15.00	3.00	23.00
MEAN			4.50	3.840	17.9800	59.000	18.800	2.2000	654.200
STDEV			.418	.6348	10.5956	33.867	13.480	1.6432	1367.35

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001263-LU-10-S1								
	29038-LFH	830725	310.00	530.00	130.00	20.00	10.000	.054
	29039-AE	830725	9.00	26.00	110.00	1.40	22.000	.073
	29040-BF	830725	5.00	22.00	110.00	1.60	21.000	.840
	29041-BC	830725	4.00	18.00	47.00	.71	15.000	.240
	29042-C	830725	3.00	20.00	60.00	.79	11.000	.170
MEAN			66.2000	123.20	91.400	4.9000	15.8000	.27540
STDEV			136.3074	227.43	35.844	8.4498	5.54076	.32447

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001263-LU-10-S1								
	29038-LFH	830725	.100	.0097	.160	.110	.0110	91.00
	29039-AE	830725	.058	.0003	.200	.070	.0004	11.00
	29040-BF	830725	1.200	.0004	1.300	1.500	.0017	13.00
	29041-BC	830725	.760	.0001	.420	.850	.0013	16.00
	29042-C	830725	.380	0.0	.300	.400	.0015	12.00
MEAN			.49960	.002100	.47600	.58600	.003180	28.600
STDEV			.48150	.004251	.47147	.59844	.004400	34.933

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001263-LU-10-S1								
	29038-LFH	830725	11.00	39.40	19.0000	4.500	64.000	62.000
	29039-AE	830725	.50	1.90	2.5000	1.000	1.500	5.000
	29040-BF	830725	1.70	4.30	9.5000	6.300	4.000	12.000
	29041-BC	830725	1.30	2.80	8.5000	9.400	1.500	16.000
	29042-C	830725	.30	1.60	6.5000	12.000	1.500	22.000
MEAN			2.960	10.000	9.20000	6.64000	14.5000	23.4000
STDEV			4.531	16.469	6.09918	4.26767	27.6925	22.4455

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001269-LU-10-S2									
	29062-LFH	830725	4.2	3.50	0.0	0.0	0.0	0.0	2000.00
	29063-AEJ	830725	4.6	3.60	11.30	42.00	54.00	4.00	16.00
	29064-BF1	830725	4.5	3.90	7.40	41.00	54.00	5.00	63.00
	29065-BF2	830725	4.7	4.10	6.10	55.00	41.00	4.00	60.00
	29066-C	830725	4.8	4.30	8.00	61.00	37.00	2.00	20.00
MEAN			4.56	3.880	6.5600	39.800	37.200	3.0000	431.800
STDEV			.230	.3347	4.1380	23.826	22.152	2.0000	876.922

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001269-LU-10-S2								
	29062-LFH	830725	450.00	740.00	75.00	16.00	9.200	.180
	29063-AEJ	830725	8.00	30.00	170.00	1.90	27.000	.180
	29064-BF1	830725	10.00	24.00	180.00	2.20	29.000	.870
	29065-BF2	830725	7.00	22.00	170.00	2.10	23.000	1.100
	29066-C	830725	2.00	3.00	50.00	.62	11.000	.320
MEAN			95.4000	163.80	129.00	4.5640	19.8400	.53000
STDEV			198.2493	322.26	61.482	6.4244	9.17213	.42708

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001269-LU-10-S2								
	29062-LFH	830725	.099	.0200	.310	.110	.0220	150.00
	29063-AEJ	830725	.097	.0003	.260	.100	.0010	7.00
	29064-BF1	830725	.310	.0020	1.100	.310	.0067	5.30
	29065-BF2	830725	.610	.0140	1.500	.640	.0430	16.00
	29066-C	830725	.370	.0016	.460	.420	.0071	8.50
MEAN			.29720	.007580	.72600	.31600	.015960	37.360
STDEV			.21370	.008879	.54770	.22634	.016998	63.100

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001269-LU-10-S2								
	29062-LFH	830725	12.20	38.20	9.5000	4.400	81.000	110.000
	29063-AEJ	830725	.70	1.10	4.0000	1.000	6.900	7.000
	29064-BF1	830725	1.00	2.00	6.5000	1.000	5.000	19.000
	29065-BF2	830725	1.30	2.90	11.0000	1.000	7.700	45.000
	29066-C	830725	.50	2.80	6.2000	4.200	3.500	12.000
MEAN			3.140	9.4000	7.44000	2.32000	20.8200	38.6000
STDEV			5.074	16.116	2.79159	1.80887	33.6816	42.5124

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001272-MOE-9-S1	29076-LFH	830727	4.2	3.50	0.0	0.0	0.0	0.0	2600.00
	29077-AE	830727	4.5	3.60	3.10	56.00	41.00	3.00	31.00
	29078-BF1	830727	5.2	4.50	3.80	86.00	14.00	.50	45.00
	29079-BF2	830727	5.1	4.40	4.10	93.00	5.00	1.00	74.00
	29080-BC	830727	5.3	4.50	2.70	98.00	2.00	.50	35.00
	29081-C	830727	5.4	4.70	3.10	94.00	6.00	.50	24.00
MEAN			4.95	4.200	2.8000	71.167	11.333	.9167	468.167
STDEV			.485	.5138	1.4642	38.034	15.306	1.0685	1044.53

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001272-MOE-9-S1	29076-LFH	830727	73.00	710.00	46.00	16.00	13.000	.085
	29077-AE	830727	7.00	29.00	96.00	1.20	21.000	.092
	29078-BF1	830727	3.00	9.00	44.00	.71	7.200	.340
	29079-BF2	830727	2.00	3.00	55.00	.95	10.000	.270
	29080-BC	830727	1.00	1.00	42.00	.60	9.400	.260
	29081-C	830727	5.70	1.00	18.00	.30	3.900	.190
MEAN			15.2833	125.50	50.167	3.2933	10.7500	.20617
STDEV			28.3655	286.54	25.616	6.2325	5.86575	.10282

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SS04
6001272-MOE-9-S1	29076-LFH	830727	.100	.0096	.210	.140	.0110	170.00
	29077-AE	830727	.072	0.0	.140	.140	.0002	6.50
	29078-BF1	830727	.530	0.0	.600	.760	.0011	16.00
	29079-BF2	830727	.940	.0005	.370	.970	.0017	5.40
	29080-BC	830727	.400	.0011	.300	.470	.0023	7.40
	29081-C	830727	.300	.0016	.250	.290	.0034	7.50
MEAN			.39033	.002133	.31167	.46167	.003283	35.467
STDEV			.32110	.003711	.16142	.34173	.003932	66.017

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001272-MOE-9-S1	29076-LFH	830727	6.50	28.20	13.0000	5.100	68.000	66.000
	29077-AE	830727	.50	1.40	3.2000	1.000	1.500	3.500
	29078-BF1	830727	.70	1.80	8.7000	5.300	1.500	9.000
	29079-BF2	830727	.50	2.30	6.6000	7.700	1.500	10.000
	29080-BC	830727	.30	4.60	5.8000	8.300	1.500	11.000
	29081-C	830727	.30	.90	10.0000	7.800	1.500	11.000
MEAN			1.467	6.5333	7.88333	5.86667	12.5833	18.4167
STDEV			2.470	10.692	3.44233	2.74275	27.1485	23.4785

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001260-6A-22-S1									
	29022-LFH	830727	3.8	2.90	0.0	0.0	0.0	0.0	3600.00
	29023-AEJ	830727	4.3	3.50	5.60	35.00	64.00	1.00	84.00
	29024-BF1	830727	4.8	4.40	6.80	40.00	58.00	2.00	74.00
	29025-BF2	830727	5.2	4.80	7.90	48.00	53.00	.50	36.00
	29026-BC	830727	5.3	4.70	72.20	87.00	14.00	.50	61.00
MEAN			4.68	4.060	18.5000	42.000	37.800	.8000	771.000
STDEV			.630	.8264	30.1728	31.137	28.813	.7583	1581.56

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001260-6A-22-S1								
	29022-LFH	830727	520.00	380.00	190.00	25.00	12.000	.052
	29023-AEJ	830727	7.00	26.00	220.00	2.80	29.000	.059
	29024-BF1	830727	7.00	24.00	94.00	1.40	13.000	.240
	29025-BF2	830727	2.00	15.00	21.00	.46	2.700	.068
	29026-BC	830727	7.00	19.00	17.00	.58	2.500	.150
MEAN			108.6000	92.800	108.40	6.0480	11.8400	.11380
STDEV			229.9898	160.61	93.959	10.636	10.8006	.08087

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SS04
6001260-6A-22-S1								
	29022-LFH	830727	.110	.0048	.160	.100	.0063	100.00
	29023-AEJ	830727	.064	.0001	.200	.070	.0002	7.10
	29024-BF1	830727	.590	0.0	1.200	.760	.0006	13.00
	29025-BF2	830727	.280	0.0	.400	.330	.0008	13.00
	29026-BC	830727	.250	.0025	.660	.270	.0063	12.00
MEAN			.25880	.001480	.52400	.30600	.002840	29.020
STDEV			.20634	.002142	.42671	.27664	.003166	39.754

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001260-6A-22-S1								
	29022-LFH	830727	13.20	41.80	15.0000	5.600	65.000	40.000
	29023-AEJ	830727	.40	1.20	5.2000	1.000	1.500	4.200
	29024-BF1	830727	.90	2.50	9.2000	10.000	1.500	12.000
	29025-BF2	830727	.50	.90	12.0000	11.000	1.500	12.000
	29026-BC	830727	.40	1.00	25.0000	12.000	1.500	22.000
MEAN			3.080	9.4800	13.2800	7.92000	14.2000	18.0400
STDEV			5.661	18.079	7.48144	4.57515	28.3981	13.8061

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	PHEW	PHECA	%GRAVEL	SAND	SILT	CLAY	CAESC
6001270-6A-22-S2									
	29067-LFH	830727	3.6	2.80	0.0	0.0	0.0	0.0	1100.00
	29068-AEJ	830727	4.5	3.60	8.70	32.00	63.00	5.00	37.00
	29069-BF1	830727	5.1	4.50	21.10	56.00	40.00	4.00	37.00
	29070-BF2	830727	5.4	5.00	33.40	63.00	36.00	1.00	29.00
MEAN			4.65	3.975	15.8000	37.750	34.750	2.5000	300.750
STDEV			.794	.9743	14.5820	28.453	26.043	2.3805	532.847

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	MGESC	KKESC	ALESC	CEC	ALECA	FEEPY
6001270-6A-22-S2								
	29067-LFH	830727	260.00	610.00	480.00	14.00	33.000	.140
	29068-AEJ	830727	5.00	36.00	290.00	3.20	35.000	.200
	29069-BF1	830727	4.00	17.00	80.00	1.10	7.800	.310
	29070-BF2	830727	3.00	15.00	2.50	.23	.850	.073
MEAN			68.0000	169.50	213.13	4.6325	19.1625	.18075
STDEV			128.0026	293.82	215.42	6.3682	17.3854	.10058

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	ALEPY	MNEPY	FEEDI	ALEDI	MNEDI	SSO4
6001270-6A-22-S2								
	29067-LFH	830727	.190	.0016	.230	.210	.0034	88.00
	29068-AEJ	830727	.160	.0001	.410	.180	.0013	7.40
	29069-BF1	830727	.760	.0004	1.400	1.200	.0011	18.00
	29070-BF2	830727	.330	0.0	.790	.540	.0009	14.00
MEAN			.36000	.000525	.70750	.53250	.001675	31.850
STDEV			.27677	.000737	.51732	.47395	.001162	37.688

PUKASKWA SOIL REPORT

LOCATION CODE	SAMPLE HORIZON	DATE	NNTK	COD	CUUT	NIUT	PBUT	ZINC
6001270-6A-22-S2								
	29067-LFH	830727	6.80	35.90	8.5000	3.900	29.000	44.000
	29068-AEJ	830727	.40	1.90	3.5000	1.000	3.400	4.700
	29069-BF1	830727	1.00	2.80	10.0000	6.900	4.900	12.000
	29070-BF2	830727	.40	1.20	15.0000	9.900	4.800	16.000
MEAN			2.150	10.450	9.25000	5.42500	10.5250	19.1750
STDEV			3.113	16.979	4.73462	3.83438	12.3357	17.1985